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THE MANAGEMENT OF WAR WOUNDS OF THE CHEST IN A BASE CENTER

THE ROLE OF EARLY PULMONARY DECORTICATION

LIEUTENANT COLONEL PAUL C. SAMSON, MAJOR THOMAS H. BURFORD,
MAJOR LYMAN A. BREWER, III, AND MAJOR BENJAMIN BURBANK
MEDICAL CORPS, ARMY OF THE UNITED STATES

THE establishment of a thoracic surgical center in a fixed hospital in the North African Theater of Operations at the beginning of the Sicilian Campaign was a far-reaching step in improving medical care for the wounded. The utilization of thoracic surgical teams of an auxiliary surgical group in the designated center provided qualified personnel for the surgical management of individuals who incurred thoracic wounds. Experience indicated that such a center was necessary because certain operative procedures cannot be unduly delayed. For example, complete pulmonary mobilization (decortication) should not be deferred for the period of time usually necessary to return the patient to a specialty center in the Zone of Interior. Thus, a factor of prime importance is that much of the thoracic surgery must be properly spaced in time and a forward thoracic surgical center is an essential part of such a program for the management of thoracic injuries encountered in war.

Some of the more important problems encountered in a forward thoracic center have been: the proper definitive management of hemothorax, including its complications of clotting, organization, and infection; a rational surgical therapy for post-traumatic empyema; the establishment of sound indications for early pulmonary decortication; the precise localization of intrathoracic foreign bodies and a critical evaluation as to the advisability of their removal. There follows a discussion of these problems, illustrated by case reports selected from the group of patients who were operated upon in the first thoracic surgery

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center established in Natousa. In nearly all cases the operation described is but one of a number of similar operations that have been performed. In general, the operative procedures represent trends of therapy as they evolved on the service during the eight months following its inception. Our experience to date has encompassed the care of approximately 1,500 patients with major thoracic injuries.

HEMOTHORAX

Intrapleural blood was present in practically all cases of intrathoracic injury. The treatment consisted of frequent thoracentesis until all blood was removed; air replacement was not practiced. Any vigorous attempt to empty the thorax was not started until the third or fourth day after injury. During the first three days aspiration was done only for the relief of pressure symptoms or for diagnosis. Cessation of pulmonary hemorrhage and of air leakage is facilitated by partial compression of the lung. Air replacement was not found feasible. In the forward hospitals, and under conditions of early and repeated evacuations, air replacement could not be well controlled; when empyema did occur following air replacement the infection was invariably more extensive because of the ever-present apical collapse. Fever was occasionally seen accompanying hemothorax and it usually subsided within a few days. When it was sustained for more than one week, however, infection was always suspected.

Contrary to civilian teaching, blood has been found to clot frequently in the pleural cavity but this has not necessarily prevented either its removal or its absorption. Aspiration needles up to No. 15 gauge have been employed and large amounts of "current jellylike" material successfully removed on several occasions. Extensive clotting may occur within a few hours following injury. In some instances the blood can be aspirated several days later; in others, the clot remains firm and defies every effort at removal through a needle. When blood and clots were unobtainable by thoracentesis, it has not been possible in any case to aspirate further significant amounts by using catheter suction.

ORGANIZING HEMOTHORAX: THE RATIONALE OF EARLY PULMONARY DECORTICATION

The process of clotting will frequently lead to organization and the factors responsible for clotting and organization are not clear. The presence or absence of intrapleural air has no apparent bearing on the clotting mechanism. Transient bacterial contamination is a possible factor, at least in some cases. For proper understanding of organizing hemothorax, certain fundamentals in its pathogenesis must be considered. These relate particularly to early decortication as a rational therapeutic measure. There is no "thickening" of either the visceral or parietal pleural layers as is often described roentgenographically. The current practice of referring to such peripheral obscuration by the term "thickened pleura" is a misnomer and should be discontinued. Within two or three days following injury there is deposited a thin layer of clotted blood and fibrin which is continuous over both visceral and parietal pleural surfaces. A closed sac or envelope is thus formed, the "inner" surface of which is toward

the hemothorax and the "outer" surface, loosely adherent to the pleura. Within seven days there is microscopic evidence of fibroblastic and angioblastic proliferation in this layer. The process is first visible extending into the walls of the envelope from the pleural surfaces. The "peel" or "rind" or "fibroblastic membrane" then increases in thickness through the progressive invasion, by fibroblasts, of the clotted blood and fibrin which become freshly attached to the inner surface of the envelope. Within four weeks, adult fibrous tissue can be seen forming the outer portion of the peel and the fibers and nuclei have arranged themselves roughly parallel to the outer surface. Most of the capillaries, however, extend at right angles to this surface and have obviously penetrated from the pleurae. The advancing inner border of active organization remains composed of young cellular tissue, and even single wandering fibroblasts can be seen. Within six or seven weeks small arterioles with smooth muscle fibers in the walls can be demonstrated at or near the outer surface of the peel. The membrane may reach a thickness of 1 cm. over the visceral pleura. For some reason as yet unexplained, the peel over the parietal pleura is always thicker, more adherent, and more vascular than that on the visceral pleura. When fully developed the peel is an entirely inelastic, fibrous membrane, which, by its firm adherence, keeps the lung compressed and immobilized. Eventually there is complete fibrous tissue and vascular union with the pleura, which then loses its identity as a delimiting membrane.

It has been an important observation that the development of infection and empyema in a hemothorax has not changed the process of organization to any appreciable degree. There is no evidence that the production of fibrous tissue proceeds at any faster rate, nor that there is any firmer union between the peel and the underlying pleura, after infection has supervened. Microscopically, the only evidence of inflammation is found on the inner surface of the peel where fibrin or blood clot in the process of organization shows infiltration by varying numbers of polymorphonuclear leucocytes.

The operation of decortication was first proposed in 1893. At that time Fowler first pointed out the necessity for removing the fibrous investment on the pleura in chronic suppurative disease if pulmonary expansion was to be obtained. Délorme almost simultaneously and quite independently recognized the same principle. Despite the unquestioned validity of this concept, the procedure never enjoyed wide usage. This was due to several factors. The first of these was the inadequacy of anesthesia at that time. Blood transfusions were not available to these early surgeons. The lack of bacteriostatic agents such as the sulfonamides and penicillin made surgery extremely hazardous when it was performed in the face of fresh suppuration. After many months of chronic infection such a degree of cellular intimacy existed between the pleura and the investing layer of organized exudate that attempts at decortication were more often failures than not.

The surprisingly large number of patients with organizing hemothorax who have been seen so far in World War II has given us the opportunity to "rediscover" and reapply the valuable concept of decortication with pulmonary

mobilization.* The early realization of its possibilities led one of us (T.H.B.) to perform the first decortication in this theater in May, 1943. Detailed studies of the pathogenesis of hemo-organization have been most fruitful in clarifying the therapeutic approach to the problems of organizing hemothorax and its infectious complications.

The indications for decortication have been varied. Its employment in patients with infected hemothorax and hemothoracic empyema will be elaborated upon in later sections. Decortication with complete visceral pleurolysis has now been performed on more than 100 patients with no postoperative deaths. In approximately 20 per cent, the presence of an organizing hemothorax with partial pulmonary compression was a complicating factor in patients who were primarily operated upon for the removal of an intrapulmonary foreign body. In uninfected organizing hemothorax, decortication has an important place in treating a small group of patients. The general indications for operation are as follows: Patients in whom there is at least a 50 per cent compression of the lung, especially if the apex is collapsed; those in whom aspiration has been unsuccessful and in whom there has been no appreciable pulmonary expansion at the end of four to six weeks following injury. In these individuals decortication will result in immediate pulmonary re-expansion and will prevent the development of a possible fibrothorax and chronic pulmonary invalidism. At least the patient will be saved a prolonged convalescence of many months and the hazards of supervening infection.

An important consideration is the proper staging of the operation in time. From a purely technical point of view, decortication is best performed from three to five weeks following injury. If performed less than two weeks after injury the peel is thin and friable; the operation is tedious because the poorly defined membrane must be removed piecemeal or meticulously wiped from the pleural surface. When performed too late (probably after ten to fourteen weeks) the fibrous union between peel and pleura is often so firm that a proper cleavage plane cannot be established. The visceral pleura is frequently torn and the lung does not expand readily because of fibrous ingrowths along the septa.

The operation of decortication entails open thoracotomy. Clot evacuation alone is not a sufficient procedure. Concomitant lesions in the thoracic parietes, lung, or mediastinum are handled as may be indicated. Important technical considerations are (1) meticulous establishment of the proper cleavage plane between peel and visceral pleura; (2) careful blunt dissection of the peel either

*Although it is not customary to insert editorial comments on articles published in the JOURNAL, the editor feels impelled to correct the impression that the principle of decortication has not been used much in the treatment of chronic empyema. The editor himself, as well as many thoracic surgeons throughout the world for many years, has found the procedure to be very useful in some cases. It is not applicable, however, to all cases. Sometimes the hemorrhage encountered is too great to permit a continuation of the operation. Sometimes also, especially in those cases in which hemorrhage is a prominent feature, the amount of scar tissue in the lung is so great that re-expansion cannot occur even if decortication is performed. In spite of these comments the authors of the article deserve great credit for applying the principle to cases of hemothorax early enough to make it possible to free the lung from what would otherwise be a compressing encasement of scar tissue. For that reason the editor regards this work as a very important contribution to the treatment of traumatic hemothorax.—EDITOR.

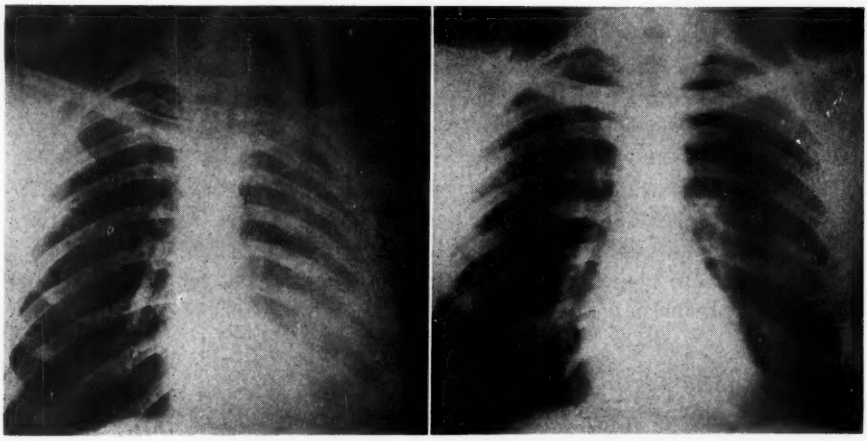
digitally or by a gauze "dissector"; (3) complete freeing of the lung where it is directly adherent to the thoracic wall, to the mediastinum, or along the fissural margins, so that complete circumferential expansion can be obtained; (4) decortication and mobilization of the elevated, fixed diaphragm, with particular attention to redeveloping the costophrenic sulcus; (5) deliberate intermittent expansion of the lung under increasing positive pressure, with careful stroking of atelectatic areas. Attempts at immediate complete pulmonary re-expansion are ill advised. On removal of the constricting peel there is exposed a grossly normal, thin, translucent, expansible pleura. A considerable amount of oozing occurs, readily explained, when it is remembered that numerous capillaries are torn and left with gaping ends which open on the pleural surface. The bleeding is immediately controlled by expanding the lung with slight positive pressure.

Reference is again made to the greater thickness and vascularity of that portion of the peel which is adherent to the parietal pleura. Removal of this membrane has not resulted in any significant increase in thoracic wall mobility. The bleeding has been relatively severe and, of course, not controlled by pulmonary re-expansion. From our experience, we would condemn the routine removal of this peel as unnecessarily increasing the hazards of the operation, without appreciably adding to its benefits.

CASE 1.—A 27-year-old American soldier sustained an accidental "sucking" wound of the left anterior thorax during bayonet practice on June 11, 1943. Immediate water-seal catheter drainage was instituted and maintained for forty-eight hours because of tension hemopneumothorax. The sucking wound was trimmed and closed. Later, repeated thoracentesis were unproductive of fluid. The patient was admitted to the thoracic surgery service on July 10. Dyspnea on exertion had increased slightly during the preceding two weeks. Anteriorly, the left chest was flattened, there was a slight scoliosis concave to the left, and expansion was appreciably limited. Horizontal expansion measurements showed the following differential: Ensiform cartilage to spine, on the right, 1½ inches; on the left ⅝ inch. Nipple to spine, on the right, 1 inch; on the left, ¼ inch. Breath sounds were distant over the entire left thorax. Analysis of serial roentgenograms showed persisting diffuse obscuration on the left side with the greater density at the base. Fig. 1*A*, taken July 14, showed the diffuse clouding which remained essentially unchanged for two weeks. The intercostal spaces were narrowed and there was slight scoliosis, concave to the left. In summary, the patient was incapacitated for everything but the most minor exercise and was not improving appreciably. The obvious cause was an organizing hemothorax with probable beginning fibrothorax.

Left-sided posterior thoracotomy with decortication was performed on July 16 (thirty-five days after injury) under endotracheal nitrous oxide-oxygen ether anesthesia. The pleural cavity was entered through the bed of the resected sixth rib. Clotted and degenerating blood occupied a space which extended from apex to base and forward to the mid-axillary line. More than 500 c.c. of this material were evacuated. The peel adherent to the visceral pleura was 3 mm. in thickness; that adherent to the parietal pleura was 5 mm. The visceral layer was completely removed by blunt dissection exposing normal pleura beneath. Microscopically this portion of the envelope showed adult fibrous tissue, with many penetrating capillaries, the latter being larger and more numerous on the surface next to the visceral pleura. There was immediate and almost complete expansion of the lung under slight positive pressure. In one area a few bubbles of air escaped from a small tear in the visceral pleura. The thoracic wall was closed in layers with interrupted silk and no

drainage tubes were used. Frequent thoracenteses were performed the first five days following operation. A roentgenogram, taken twenty days postoperatively, showed complete pulmonary re-expansion at the apex and a small residual lateral pneumothorax. Thoracic measurements were taken thirty days after operation. The horizontal expansion from the ensiform cartilage to the spine was 1¾ inches on the right, and 1½ inches on the left. The horizontal nipple to spine expansion was one inch on both sides. The patient was discharged to limited duty in sixty days. A follow-up roentgenogram, taken on Jan. 6, 1944 (Fig. 1*B*), showed an essentially normal left thorax.



A. *B.*

Fig. 1.—*A*, There is diffuse left-sided obscuration. The intercostal spaces are narrowed. *B*, Five months following surgery, the left thorax is completely normal.

CASE 2.—A 19-year-old German prisoner sustained nonsucking perforating wounds of the left thorax from a high explosive fragment. The small wound of entry was located in the second interspace in the midclavicular line. The wound of exit, slightly larger, was in the eighth interspace in the midscapular line. The wounds were débrided approximately twenty-four hours after injury. At that time, roentgenograms revealed a left-sided hemothorax which was causing an approximate forty-five per cent collapse of the lung. Thoracentesis was performed but no fluid was obtained. During the next eight days the patient continued to be febrile, the temperature on one occasion reaching 103.2° F. Repeated aspirations during this period yielded only clot fragments and shreds of fibrin. Smears and cultures of this material were consistently negative for organisms. A roentgenogram was taken nine days following injury (Fig. 2). The left hemothorax was obscured and the lung compressed. One day later a No. 22 catheter was inserted in the left pleural cavity posteriorly. It was connected to a water-seal bottle and mild continuous suction applied, but neither fluid nor clot could be evacuated. Because of the continued fever it seemed probable that in spite of repeated negative cultures, infection was developing in the obviously clotted hemothorax. Accordingly, thoracotomy with clot evacuation and visceral pleural decortication was performed fourteen days after injury. Under intratracheal nitrous oxide-oxygen ether anesthesia a posterolateral incision was made through the sixth intercostal space without removing or sectioning ribs. When the thorax was entered it was found, as is customary in such cases, that the hemothorax was larger than would have been assumed from the roentgenograms. The pleural cavity was filled with clot and loculated pools of thick, syrupy blood. The lung was held completely immobile by a thin (2 mm.) peel of fibrin which was undergoing early organization. Strikingly, even positive pressure up to

15 cm. of water did not result in any pulmonary expansion. Decortication was technically tedious due to the thinness and friability of the peel. It stripped easily but piecemeal removal was necessary. The underlying visceral pleura was grossly normal and did not bleed. Following complete visceral pleurolysis, the lung promptly expanded to fill the hemothorax. The wounds of entrance and exit in the upper lobe were solid and the fibrin peel over both areas was left undisturbed. Neither intrapulmonary hematoma nor areas of contusion could be palpated. The diaphragm was freed and immediately resumed normal excursions. No attempt was made to decorticate the parietal pleura. After thorough cleansing, the pleural cavity was filled with warm physiologic saline solution and the lung slowly inflated. No air leaks were observed. Two intercostal tubes were inserted; the anterior tube, a No. 14 Pezzer catheter, was placed in the second interspace just lateral to the midclavicular line; the second, a soft rubber tube with an inside diameter of ¼ inch, was fenestrated for a distance of 7 cm. inside the thorax and brought out through the eighth interspace in the posterior axillary line. The proximal end was cut obliquely and attached to the parietal pleura with a single silk suture so that it extended vertically but lay flat against the intrathoracic parietes. The third to the ninth intercostal nerves were blocked intrapleurally with

Fig. 2.—There is a left-sided organizing hemothorax with apical compression.

2 per cent procaine and the thorax was closed in layers with interrupted silk. Following this the lung was gradually expanded under positive pressure at the height of expansion, the intercostal tubes were first clamped, the patient rolled on his back, and the tubes then connected to water-seal bottles. Culture of the clot and culture of the peel were made at operation and both were negative for organisms on aerobic and anaerobic media. The anterior tube was removed after twenty-four hours and the posterior tube, on the third day. Following this, the patient was allowed out of bed. A roentgenogram, made on the seventh postoperative day showed complete left-sided pulmonary re-expansion. The patient was evacuated to a convalescent camp for prisoners of war on the fourteenth day postoperatively.

INFECTED OR CONTAMINATED HEMOTHORAX

Proof of the infection was based on the finding of organisms in the grossly sanguineous fluid aspirated from patients who showed clinical signs of toxicity. Frequently, however, smears and cultures did not become positive for many days. In these cases infection was presumed if the patient remained toxic, con-

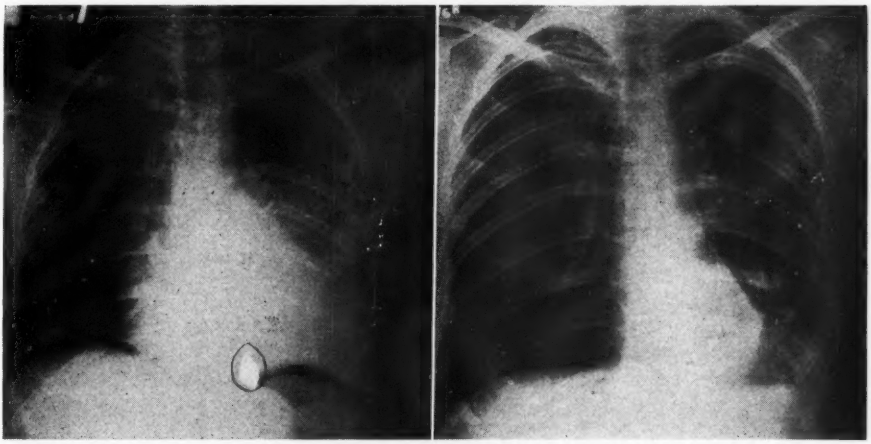
tinued to have a fever, or showed any increase in the amount of pleural fluid which could not be explained on the basis of further bleeding. A wide variety of organisms have been implicated but the frequency with which anaerobic streptococci and staphylococci were encountered has been somewhat surprising. Non-gas-forming clostridial organisms have caused infections in a small but interesting group of patients and they are now being investigated further. Clotting and organization have been present in nearly all cases where infection has supervened.

The proper handling of these patients has presented many difficulties. It has always been possible to treat them conservatively, aspirate until "thick" pus was present, and then drain the empyema. This has been the usual procedure in patients with small infected hemothoraces. When there is a large infected hemothorax, however, with more than a 25 per cent compression of the lung, such a policy will frequently result in extensive, relatively stationary empyema cavities. A large percentage join that deplorable group of patients with chronic empyema who, after months and even years of suppuration, are relieved by death or are "cured" by multi-staged, deforming, obliterative operations. In a number of patients with infected hemothorax where the lung was significantly collapsed, we have employed formal thoracotomy with evacuation of all exudate, complete decortication of the visceral pleural peel, immediate pulmonary re-expansion, and layered closure of the incision. Water-seal intercostal drainage tubes have been used routinely. Following discovery of the intrapleural infection, these operations were undertaken as soon as it was possible to render the patient a satisfactory operative risk. In the majority of patients so treated, no subsequent empyema developed and there was primary union of the thoracic incision. In the remainder a small, residual, basal empyema was found easy to control. In the early cases, crystalline sulfanilamide was placed in the pleural cavity. More recently, greater "protection" against residual infection has been gained by the use of local and systemic penicillin.

CASE 3.—A 19-year-old private sustained a penetrating wound of the left thorax on Sept. 11, 1943, on the Salerno Beachhead. There was no hemoptysis or dyspnea at any time. Roentgenograms taken September 16, showed a large shell fragment lying well posteriorly at the level of the left tenth interspace. There was a moderate-sized hemothorax. At this time the patient was moderately toxic. The fever increased progressively, the highest being 103.4° F. Repeated aspirations were productive only of small amounts of sterile, old blood. Following the induction of diagnostic pneumoperitoneum, roentgenograms of September 20 (Fig. 3*A*) showed the fluid to be increasing in the left thorax in spite of repeated thoracentesis. The shell fragment was unquestionably intrapleural.* On September 23 left posterior thoracotomy was performed. The thorax was opened through the sixth intercostal space after posterior segments of the sixth and seventh ribs had been removed. The lung was collapsed and there was extensive clotting of the blood with early organization. The shell fragment was intrapleural and measured 22 by 16 by 11 mm. No clothing was attached to it. The fragment lay in a loculus of clotted blood which had a putrid odor and which was mixed with greenish exudate. After emptying the pleural cavity, the peel was removed from the visceral pleura, leaving it relatively normal. The lower half of the lower lobe was badly lacerated and necrotic; therefore, a segmental lobectomy was done. Ten grams of crystalline sulfanilamide were dusted into the pleural cavity and the incision. The

*See discussion of diagnostic pneumoperitoneum in "Experiences in the Localization of Thoracic Foreign Bodies," Burbank et al., p. 64.

thoracic wall was closed in layers with interrupted silk and a posterior intercostal water-seal tube was introduced. Cultures showed a mixture of staphylococci and anaerobic non-hemolytic streptococci. Immediate postoperative bronchoscopy was productive of blood-streaked mucus. Following operation the lung expanded well at the apex but a loculated pocket of serosanguineous fluid developed in the axilla which cleared with aspiration. The fever continued from 101 to 103° F. for two weeks. Drainage from the intercostal tube rapidly became purulent. By October 10, the drainage had ceased and the pleural cavity seemed very small; accordingly the intercostal tube was removed. There was an immediate flare-up of fever and roentgenograms showed increased basal obscuration. On October 16, open thoracostomy with rib resection and tube drainage was done under local anesthesia and the small empyema was rapidly obliterated thereafter. Roentgenograms taken on November 13 (Fig. 3*B*) showed complete left-sided pulmonary expansion with minimal pleural reaction at the base. The patient was evacuated to the Zone of Interior in excellent condition.

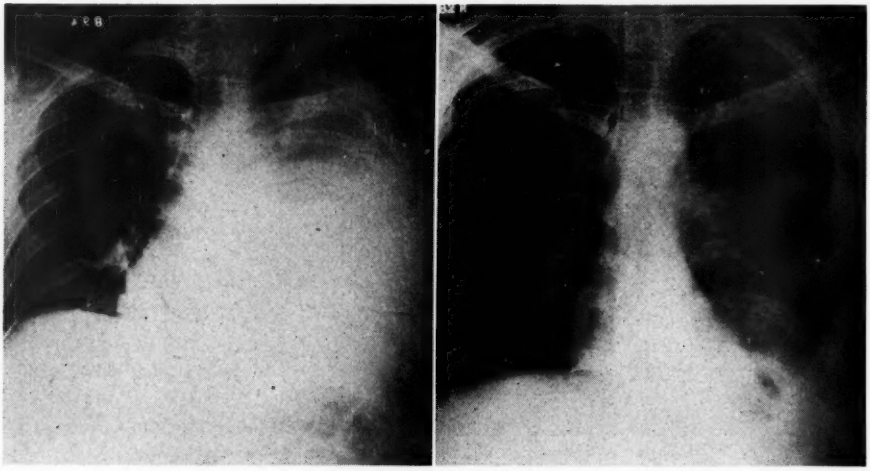


A. *B.*

Fig. 3.—*A*, A diagnostic pneumoperitoneum has been induced. The left-sided hemothorax has increased in spite of repeated thoracentesis. *B*, Two months following the thoracotomy and one month following thoracostomy, the left thorax is almost entirely clear.

CASE 4.—A 26-year-old soldier suffered a perforating "sucking" wound of the left posterior thorax on Sept. 21, 1943. There were also compound comminuted fractures of the seventh, eighth, and ninth ribs posteriorly. On the day of injury the sucking wound was closed surgically by using a strip of latissimus dorsi to reinforce the intercostal muscles. The skin was not sutured. Five days following his injury the patient was apparently recovering satisfactorily. A frontal roentgenogram showed probable encapsulated pleural fluid superimposed on the cardiac shadow, a moderate amount of pulmonary infiltration due to bleeding, and fractures of the seventh, eighth, and ninth ribs posteriorly. On the tenth day after injury the patient rapidly became dyspneic and developed a sensation of tightness in the thorax and abdomen. He was transferred for emergency treatment at the thoracic surgery center. Temperature was ranging from 100 to 102° F. The left-sided hemothorax had increased greatly and there was some cardiac shift to the right. Fifteen hundred cubic centimeters of dark blood were aspirated immediately and there was great subjective improvement. Smear and cultures of this fluid were negative for bacteria. In the next forty-eight hours there was evidence of increasing intrapleural pressure although no further blood could be aspirated. Fig. 4*A*, taken at this time, showed the persisting increased left-sided obscuration with resultant cardiac and mediastinal shift. Left posterior thoracotomy was

performed on October 5, fourteen days after injury. The posterior granulating wound (site of the pleural closure) was widely excised and the incision extended to the midaxillary line. Fragmented portions of the three fractured ribs were removed and the pleural cavity was entered through the eighth intercostal space. There was some bleeding from the eighth intercostal artery. The lung was 75 per cent collapsed and the pleural space was filled with approximately 1,000 c.c. of firmly clotted blood. Practically no liquid blood was present. There was very early organization of the fibrin and a thin layer was removed from the visceral pleural surface. Posterolaterally there was a laceration 3 cm. deep in the upper lobe which contained four fragments of rib. The lung bled briskly when these were removed. The laceration was trimmed and repaired with fine silk. Anterior and posterolateral intercostal drainage tubes were introduced and connected with water-seal bottles. Grossly and microscopically, the organizing exudate showed miliary abscesses. Culture of the blood clot removed at operation was positive for aerobic hemolytic *Staphylococcus aureus*. The closure in the thoracic wall was difficult posteriorly where the wound of entrance had been excised.



A. *B.*

Fig. 4.—*A*, A large hemothorax with cardiac shift is still present one week later, in spite of thoracentesis. *B*, The pulmonary field is clear. The flattened posteriolateral empyema is well drained.

Thin purulent drainage was evident from the lower tube in forty-eight hours. At this time a roentgenogram showed the lung to be well expanded at the apex. Laterally there was an oval area of obscuration which later proved to be a small loculated empyema. In seven days the previously excised posterior portion of the incision had become grossly infected. Two weeks postoperatively it was evident that the localized empyema was connected with a small bronchopleural fistula and was being inadequately drained by the intercostal tube. Accordingly, a 15 cm. segment of the ninth rib was removed, the empyema cavity opened widely, and packed. Following this operation, the patient convalesced rapidly and the small bronchial fistula closed. Evacuation to the Zone of Interior was accomplished six weeks later. At this time the roentgenogram showed good pulmonary expansion. The lateral and basal obscuration had almost entirely cleared (Fig. 4*B*).

CASE 5.—A 34-year-old private sustained a "sucking" wound of the right posterior thorax Sept. 23, 1943. An immediate occlusive dressing was used and within twenty-four hours primary closure of the pleura was performed. The pleural cavity was drained with a water-seal catheter for two days. On September 27, 1,800 c.c. of air and fluid were

aspirated. On the following day the patient was admitted to the thoracic surgery service where roentgenograms showed a large amount of blood in the pleural cavity with a 75 per cent collapse of the right lung (Fig. 5*A*). On September 30, 100 c.c. of bloody fluid were aspirated with difficulty and subsequent cultures were negative for organisms. An intercostal water-seal catheter was reintroduced in an attempt to empty the pleural cavity but only 200 c.c. of old blood were obtained in twenty-four hours. On October 5, 20 c.c. of sterile fluid were aspirated, which was all that could be obtained. At this time a roentgeno-

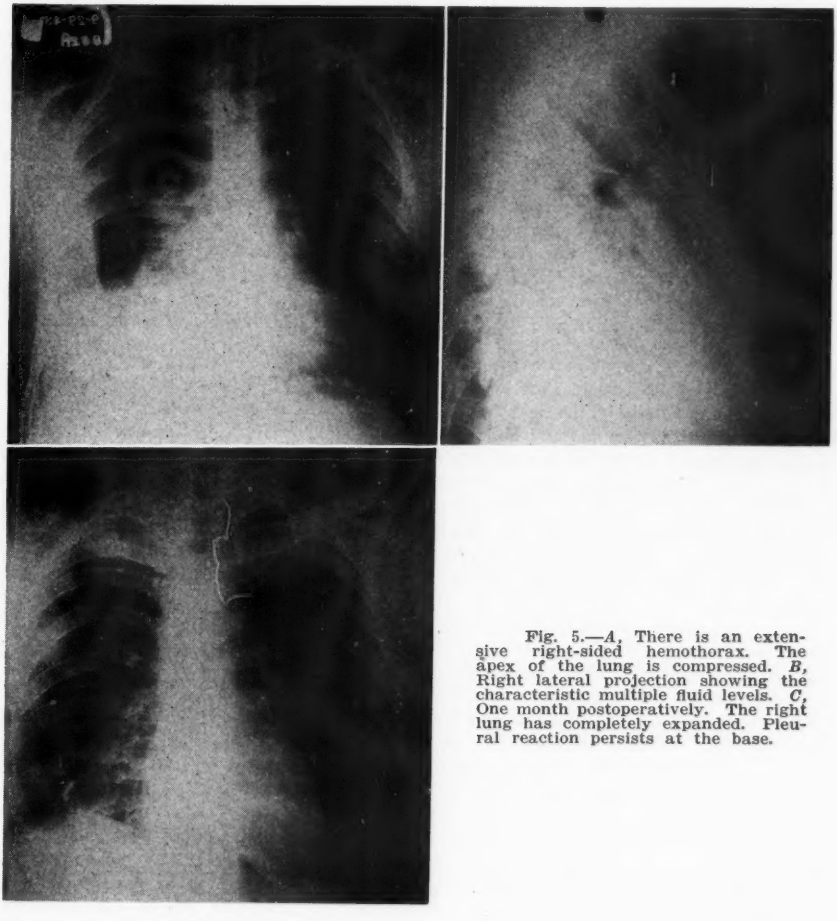


Fig. 5.—*A*, There is an extensive right-sided hemothorax. The apex of the lung is compressed. *B*, Right lateral projection showing the characteristic multiple fluid levels. *C*, One month postoperatively. The right lung has completely expanded. Pleural reaction persists at the base.

gram in the lateral projection (Fig. 5*B*) showed extensive obscuration at the base and multiple fluid levels, a characteristic of intrapleural infection. The patient continued to be toxic and his temperature showed a progressive rise, reaching a peak of 103.2° F., on October 6. Right-sided posterior thoracotomy was performed on October 7 (fourteen days after injury) under endotracheal nitrous oxide-oxygen ether anesthesia. Two small granulating

wounds of the right posterior thoracic wall were first excised and closed with separate instruments. Short posterior segments of the seventh and eighth ribs were removed and the pleural cavity was entered through the seventh intercostal space. The lung was collapsed an estimated 90 per cent and the pleural cavity was filled with liquid blood, serum, masses of fibrin, and clot in various stages of degeneration. The lung itself was bound down with the characteristic organizing exudate. A cleavage plane was eventually established and the entire peel was removed from the visceral pleura, allowing immediate and nearly complete expansion when slight positive pressures were used. The lung was lacerated at the sites of the through-and-through wounds and these areas were repaired with fine silk. Anterior and posterior intercostal water-seal tubes were used. Ten grams of crystalline sulfanilamide were placed in the pleural cavity and the wound. The incision was closed in layers with interrupted fine silk and the pericostal sutures were removed after the intercostal muscles had been sutured. Immediate postoperative bronchoscopy was productive of a moderate amount of bloody mucoid secretion. The lung was completely expanded in forty-eight hours. The anterior tube was removed at this time while the posterior tube was left in place for four days. The fever became elevated to 103° F. on the third postoperative day and then rapidly subsided. There was no wound infection and no evidence at any time that an empyema was developing. The pleural fluid, cultured at operation, showed a heavy growth of nonhemolytic streptococci. Microscopic examination of the peel revealed dense fibrinopurulent exudate beneath which was the characteristic thickened membrane of organizing fibrin, showing fibroblastic and angioblastic proliferation. A roentgenogram taken thirty days postoperatively (Fig. 5*C*) showed complete pulmonary expansion. There was a moderate residual pleural reaction at the right base. The patient was evacuated to the rear as an ambulatory patient on November 11.

CASE 6.—A 22-year-old staff sergeant sustained penetrating shell fragment wounds of the right thorax anteriorly, the right buttock, and right wrist on Nov. 10, 1943. On admission to a forward evacuation hospital he was expectorating bright blood. Because of rigidity, a laparotomy was performed approximately twelve hours after injury but no abnormality was found in the abdomen. Immediately following operation, thoracentesis yielded 500 c.c. of blood which was used as an autotransfusion. During the next ten days there was ample evidence of a bronchopleural fistula. Bloody fluid and air were frequently aspirated and on November 16 an attack of sudden dyspnea was relieved by the removal of 1,500 c.c. of air. In two selected roentgenograms (Figs. 6*A* and *B*) are shown a partially collapsed lung with numerous interpleural adhesions; extensive hemopneumothorax with multiple fluid levels; a large intrapulmonary shell fragment which, in Fig. 6*A*, is seen indistinctly at the inner end of the ninth rib posteriorly. The patient was admitted to the thoracic surgery service on November 30 and was comfortable except for moderate dyspnea. Shortly after admission 1,250 c.c. of air were removed from the pleural cavity and final manometric pressures of −12, −6 cm. of water were maintained in spite of cough. Daily thoracentesis for three days yielded a total of 1,200 c.c. of air and 500 c.c. of dark brownish red fluid. There was an elevation in temperature to 102° F. daily, and two separate smears and one culture revealed many gram-positive intracellular and extracellular nonhemolytic streptococci. Right-sided posterior intercostal thoracotomy was performed on December 4, because of the evidence of infection and increasing toxicity. The pleural cavity contained 600 c.c. of degenerating blood and exudate and the lung was subtotally collapsed. It was immobilized by firm organizing peel, partially covered by yellowish-green exudate. The apex of the lung was encased in a tubular sheath which was attached to the cupola of the thorax. After complete visceral decortication, the shell fragment, measuring 20 by 7 by 5 mm., was easily found and removed from the lower lobe. A moderate-sized bronchopleural fistula was present posterolaterally in the upper lobe and it was repaired with interrupted 000 silk. During operation the external wound and the pleural cavity were frequently dusted with sulfanilamide crystals. After thorough rinsing of the pleural cavity, 10 Gm. of crystals were introduced at the time of closure. Two water-seal drainage tubes, anteriorly and posteriorly, were provided and the posterior tube was clamped off for five hours following operation. The

lung was completely expanded in forty-eight hours and empyema did not develop. The patient was allowed out of bed in seven days. In Fig. 6*C* is shown the appearance of the thorax on the sixth postoperative day. The triangular area of density in the right cardiophrenic angle was due to a collection of fluid in the pleural cavity which absorbed without aspiration. The patient was evacuated to the rear in six weeks and was asymptomatic at that time.

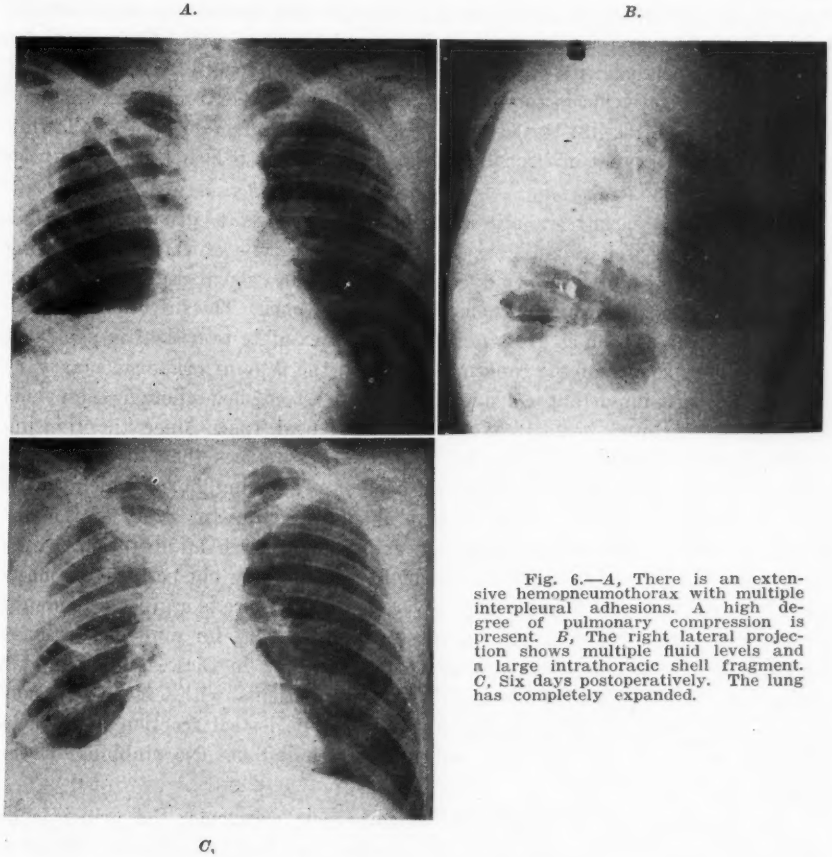


Fig. 6.—*A*, There is an extensive hemopneumothorax with multiple interpleural adhesions. A high degree of pulmonary compression is present. *B*, The right lateral projection shows multiple fluid levels and a large intrathoracic shell fragment. *C*, Six days postoperatively. The lung has completely expanded.

POST-TRAUMATIC EMPYEMA; "HEMOTHORACIC EMPYEMA"

The mechanism of development of post-traumatic empyemas varies considerably. Empyemas are caused by a rather wide variety of organisms, both aerobic and anaerobic. The infection may be introduced through the thoracic wall, as a contamination from the abdomen when the diaphragm has been perforated, or from the lung through a bronchopleural fistula.

Empyemas which follow thoracoabdominal wounds are of considerable importance as a group but they will not be considered in detail here. Suffice it to say that often there is little intrapleural bleeding and the contamination

from a perforated viscus takes place in a clean pleural cavity. The development of thick pus may be very rapid, necessitating early thoracostomy. Unless there is extensive pulmonary damage or continued contamination from organisms or bile, this type of empyema responds well to adequate drainage. Chronicity, from whatever cause, leads to marked fibrous tissue proliferation particularly beneath the parietal pleura, and considerable periosteal stimulation which results in the formation of triangular ribs. These reactions do not differ essentially from those associated with chronic postpneumonic empyema. Another type of post-traumatic empyema is fortunately rare but may be extremely troublesome to care for, as will be illustrated by Case 7. Such an infection occurs following the delayed appearance of bronchopleural fistulas after a hemothorax has been completely aspirated.

Nearly every post-traumatic empyema develops in a pre-existing hemothorax. Because of its characteristic behavior, this type of empyema is being designated as "hemothoracic empyema." There is no sharp differentiation between infected hemothorax and hemothoracic empyema. The infection is classified as empyema as soon as gross pus or purulent exudate is evident in aspirated material. The source of the contamination and the type of organism may vary but neither are important considerations. In effect, hemothoracic empyema develops in a closed hematoma of the intrapleural space since the limiting walls of the infected cavity are not the pleural surfaces themselves but are composed of a thickened membrane or peel of organizing fibrin which covers and protects the pleurae. This factor probably accounts for many of the differences from postpneumonic empyema exhibited by such an infection. In a developing hemothoracic empyema, purulent exudate may not be seen for many days; "thick" pus may not form for several weeks. There is a greater tendency for the empyema to pocket, thus increasing the necessity for multiple drainage procedures. Total empyemas are more frequent and, in these, pulmonary reexpansion is indefinitely prolonged. Even in patients with extensive hemothoracic empyemas of many weeks' duration, no periosteal reaction of the ribs has been seen and the ribs have not become triangular. No clubbing of the fingers has been observed.

In the treatment of established hemothoracic empyema, the principle of adequate dependent drainage with rib resection has been mandatory. There is no place for intercostal drainage except in the rare instance when a patient may be too ill for rib resection. In all instances there is a tremendous amount of partially degenerated clot, fibrin, and exudate which will promptly clog an intercostal catheter. The general practice of waiting for thick pus to develop must be modified if the patient is to be saved from days or weeks of toxic absorption. There seems to be no urgent reason for using a water-seal bottle to make the drainage airtight unless the empyema has developed with unusual rapidity. In hemothoracic empyema, mediastinal immobility depends on the amount of organization which has occurred in the pre-existing hemothorax and is, therefore, roughly proportional to the length of time since injury. There is

no relationship between mediastinal fixation and either the duration of the infection or the thickness of the purulent exudate.

Thoracotomy with complete visceral decortication has been successful in the early definitive treatment of a group of patients whose subacute, total, hemothoracic empyemas have persisted for from four to six weeks following adequate dependent drainage. In these, pulmonary re-expansion has been fairly prompt and the small remaining empyema cavities have, eventually, become obliterated without difficulty. Recent experience with patients who have been "protected" by penicillin shows that the indications for pulmonary mobilization may well be extended with impunity to include primary decortication in early extensive hemothoracic empyemas when there has not been a preliminary operation for drainage.* Prompt pulmonary re-expansion obliteration of the pleural cavity and primary wound healing have been the usual sequelae. In this group of patients there have been few residual empyemas to date. If further investigation proves that such a procedure is not unduly hazardous, it should mean that the problem of chronic hemothoracic empyema will become essentially nonexistent.

CASE 7.—A 24-year-old soldier was wounded by a machine-gun bullet on July 10, 1943. The bullet entered the left lateral thoracic wall, traversed both lungs, and came out the lower right axilla. The patient was admitted to the thoracic service five days later, having been evacuated from Sicily on a landing ship tank. He was slightly dyspneic and the hemoglobin was 65 per cent (Sahli). Blood smears were positive for the plasmodia of malaria. The admission roentgenogram (Fig. 7*A*) showed a right-sided pneumothorax with an approximate 25 per cent collapse, and a left-sided hemothorax. The right lung re-expanded promptly without thoracentesis. On the left, the blood was completely removed by three aspirations. After pursuing a normal course the patient became febrile ten days after admission and intensive antimalarial therapy was without avail. Serial roentgenograms revealed a vague area of slightly increased obscuration at the left base, but a thoracentesis was unproductive (Fig. 7*B*). The fever continued and on August 3 the patient suddenly expectorated a small amount of purulent sputum. A roentgenogram taken on this date (Fig. 7*C*) showed the previously noted area of obscuration to have increased. There was now a small air pocket with a fluid level visible laterally at the seventh rib and interspace. Following the aspiration of foul pus a segment of the ninth rib was removed, draining an empyema in which was demonstrated a small bronchopleural fistula.

Following this, the temperature promptly became normal. After seven days, however, there was a recrudescence of fever, again not influenced by antimalarial therapy. Attention is again directed to Fig. 7*C*. At the level of the sixth rib and interspace mesially was an area of patchy density which could be partially separated from the basal obscuration described here. Serial roentgenograms showed that this area of density increased. A thoracentesis revealed pus and on August 16, a small segment of the sixth rib was removed posteriorly, draining an interlobar collection of pus into which emptied a small bronchopleural fistula. The temperature again promptly returned to normal but became elevated after four days. Associated with this elevation the patient developed a severe toxic psychosis with profound depression and self-destructional tendencies. Productive cough returned for the third time. There also developed a sense of pressure over the left thorax anteriorly. Physical examination revealed hyperresonance over the precordium. The roentgenogram of August 22 (Fig. 7*D*) is worthy of careful study. Segments of the sixth and ninth ribs posteriorly are resected and the small empyemas well drained. There was an anterior tension pneumo-

*Burford, T. H., Parker, E. F., and Samson, P. C.: Early Pulmonary Decortication in the Treatment of Posttraumatic Empyema, Ann. Surg. 122: 163, 1945.

thorax pocket overlying the heart and extending from the midscapular line on the left, to just beyond the heart shadow on the right (lower arrows). At the level of the posterior fourth interspace and fifth rib on the mediastinum was a small triangular area of density showing a fluid level immediately beneath the inner end of the left clavicle (upper arrow). The pressure symptoms from the anterior tension pneumothorax were temporarily relieved by withdrawing air anterolaterally with a needle. The *posterior* pocket contained foul pus, and

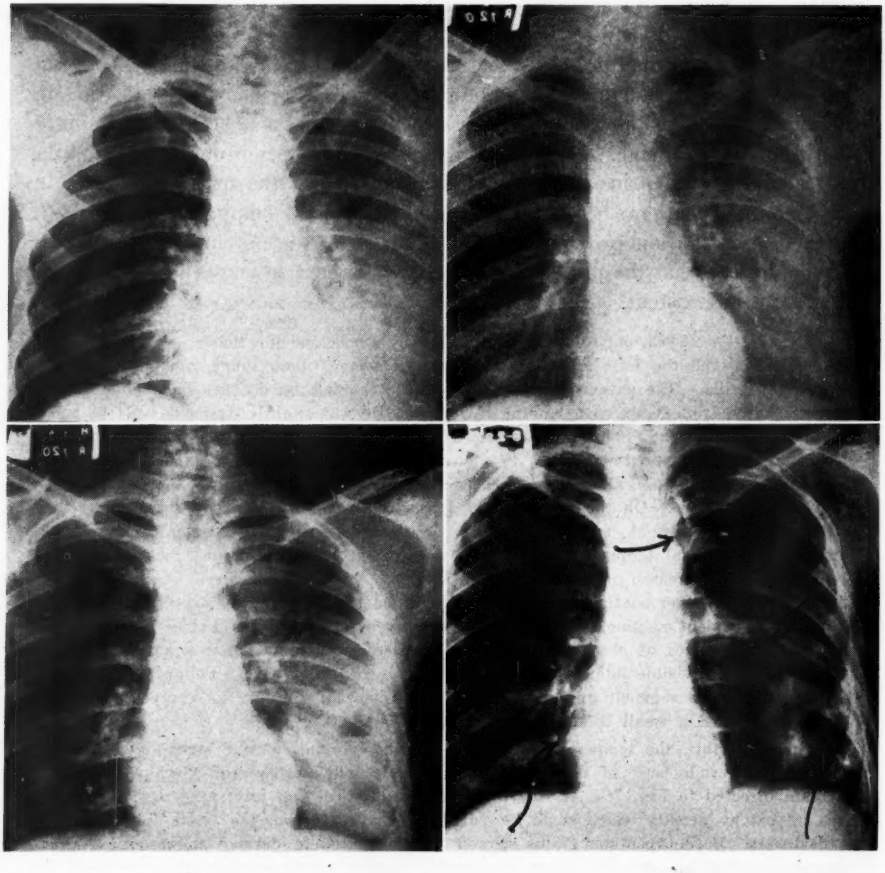


Fig. 7.—*A*, Right-sided pneumothorax; left-sided hemothorax. *B*, Slight obscuration persists at the left base. There has been complete resorption of the right-sided pneumothorax. *C*, Increased obscuration at the left base now showing an air pocket and a fluid level. *D*, There is an anterior encapsulated pneumothorax. Far mesially, at the posterior fourth intercostal space and fifth rib, is a small triangular area of density with a fluid level.

open thoracostomy with resection of the fifth rib mesial to its angle was successful in draining a small empyema between the lung and mediastinum. A bronchial communication was present. The fever *did not* return at once to normal, and pressure readings showed that tension persisted in the anterior localized pneumothorax. Accordingly, on August 25, an intercostal catheter was introduced and connected with a water-seal bottle. Within twenty-

four hours the lung was re-expanded and all evidence of air leak was absent. The catheter was removed after forty-eight hours. The temperature then promptly returned to normal, the psychosis cleared, and the patient rapidly regained his appetite, weight, and strength.

During this entire period, the patient had been on full therapeutic doses of sulfadiazine except when it was temporarily withheld in searching for the cause of the fever. Frequent transfusions were also given. When he was evacuated to the rear on September 6, the fistula in the lower posterolateral empyema had closed and this cavity was nearly obliterated. The other two cavities were clean and were rapidly diminishing in size.

The occurrence of multiple empyemas with fistulas in a traumatized lung that has fully re-expanded offers a real challenge as to the type of primary therapy to be employed if such complications are to be prevented. It is interesting to speculate upon the nature of the pathology responsible. Do the "blowouts" occur in the missile track or was there a primary vascular injury resulting in areas of pneumomalacia which later ruptured, giving rise to isolated fistulas with separate encapsulated empyema pockets? The problem of multiple empyemas requires patience and skill in the proper localization and drainage of the pus. A misplaced incision results in unnecessary mutilation as well as, at times, a threat to the patient's life. Accurate and prompt drainage will result in a cure in nearly all cases. Attempts to drain one cavity through another, even though close at hand, are usually ill conceived and may well endanger a successful outcome by tearing into relatively normal lung. Multiple rib resections are nearly always preferable.

CASE 8.—This patient was a 24-year-old officer, an Italian prisoner. On July 10, 1943, he suffered an extensive perforating, "sucking" wound of the right posterior thorax with associated compound comminuted fractures of the right scapula and the third, fifth, and sixth ribs. The wounds were débrided but an adequate early pleural closure was not performed. By July 17, persisting increased pressure was evident in the right pleural cavity and there was little clinical relief from repeated aspirations. In Fig. 8*A* is shown complete collapse of the right lung, cardiac shift, and subtotal compression of the left lung. Wide mediastinal herniation and depression of the right diaphragm complete the picture of a massive tension hemopneumothorax. The patient was in rather desperate straits at this time. An intercostal water-seal catheter was introduced on July 20, and removed on July 31. The tension was relieved during this period but the lung remained collapsed and total empyema developed. On August 2, the patient was transferred to the thoracic surgery center and on the following day thoracostomy was performed. Six centimeters of the tenth rib were resected, and a large tube was placed airtight within the pleural cavity and connected to a water-seal bottle. For the first twenty-four hours there was evidence of a small bronchopleural fistula. Thereafter, a negative pressure of from 10 to 15 cm. of water was maintained constantly in the pleural cavity for fourteen days. A roentgenogram (Fig. 8*B*) showed continued total collapse of the right lung for a period of more than four weeks in spite of adequate drainage, negative pressure, breathing exercises, and frequent irrigations with a 1:3000 aqueous solution of azochloramid. Bronchoscopic examination showed no bronchial obstruction. During this period a sequestrectomy was performed on the scapula.

Right-sided posterior thoracotomy with complete visceral decortication was performed on September 2 (eight weeks after injury). A long incision following the eighth intercostal space passed 2 cm. above the thoracostomy opening. Eighteen-centimeter lengths of the eighth and ninth ribs were removed and the seventh rib was cut mesial to its angle. The periosteal beds were formalinized and the pleural cavity entered through the bed of the ninth rib. The lung was totally collapsed and its margins were unidentifiable. (Fig. 8*C*). There was no expansion on positive pressure and the diaphragm was held depressed and immobile. By combined sharp and blunt dissection the proper cleavage plane was established

between the visceral pleura and the adherent organized exudate, which was from 5 to 6 cm. in thickness. When exposed, the visceral pleura was normally thin, showing only occasional areas where there was slight loss of translucency with subpleural scarring. The pleural surface oozed considerably. The investing peel was also removed from the diaphragm, mobilizing it completely. The apex of the lung was released from its bed at the level of the fifth

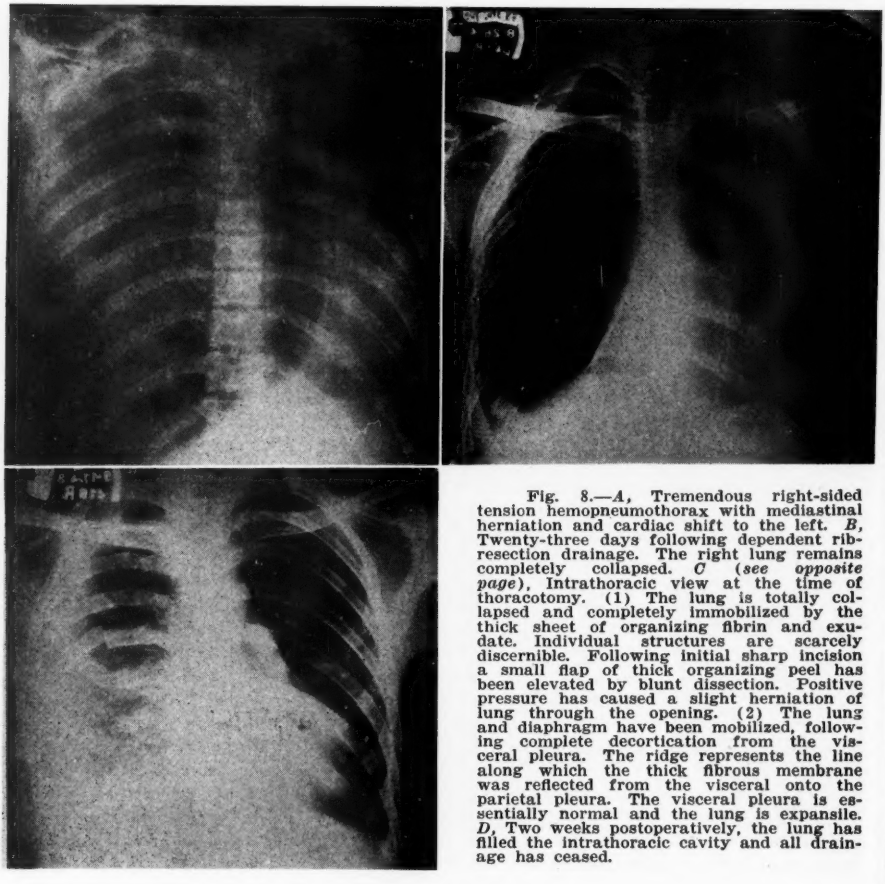


Fig. 8.—*A*, Tremendous right-sided tension hemopneumothorax with mediastinal herniation and cardiac shift to the left. *B*, Twenty-three days following dependent rib-resection drainage. The right lung remains completely collapsed. *C* (*see opposite page*), Intrathoracic view at the time of thoracotomy. (1) The lung is totally collapsed and completely immobilized by the thick sheet of organizing fibrin and exudate. Individual structures are scarcely discernible. Following initial sharp incision a small flap of thick organizing peel has been elevated by blunt dissection. Positive pressure has caused a slight herniation of lung through the opening. (2) The lung and diaphragm have been mobilized, following complete decortication from the visceral pleura. The ridge represents the line along which the thick fibrous membrane was reflected from the visceral onto the parietal pleura. The visceral pleura is essentially normal and the lung is expansile. *D*, Two weeks postoperatively, the lung has filled the intrathoracic cavity and all drainage has ceased.

rib posteriorly. Eventually the lung was completely freed including the entire mediastinal surface of the upper lobe. Slight positive pressure then produced an 80 per cent expansion. Five grams of sulfanilamide were then placed in the pleural cavity, a Pezzer catheter was introduced anteriorly in the second intercostal space, and a large tube reintroduced through the old thoracostomy opening. These were attached to water-trap bottles. The thoracic wall was closed in layers with catgut and the skin loosely approximated with silkworm gut. Twenty-four hours after operation the right lung continued to be completely aerated and was expanding well. The anterior tube was removed on the fourth postoperative day and the posterior tube, on the fifth day. At this time the lung had completely filled the thoracic

cavity and there was no drainage of any sort. Convalescence was rapid and the thoracic incision healed primarily. Two weeks postoperatively, the roentgenogram (Fig. 8*D*) showed a well-aerated right lung. The extensive peripheral reaction is to be expected in any decortication for empyema since no attempt is made to remove the thick organizing peel from the surface of the parietal pleura. There was considerable resorption of this shadow during the following six weeks. The patient reported by letter three months postoperatively. He had no complaints in reference to the thorax and there had been no further drainage.

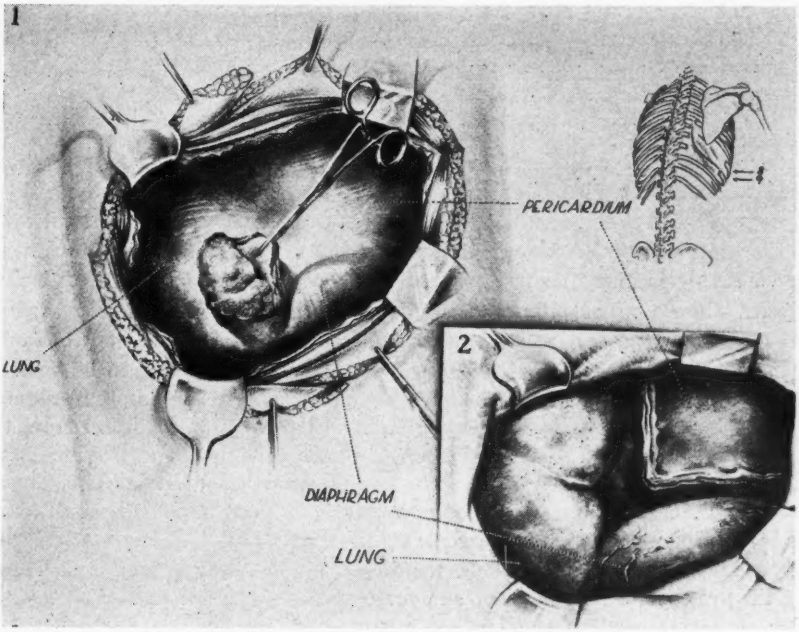


Fig. 8*C*. (*For legend see opposite page.*)

INTRATHORACIC METALLIC FOREIGN BODIES

There is no argument that accessible foreign bodies which are causing symptoms should be removed as soon as the condition of the patient warrants the operation. Intrathoracic infection may develop from bits of clothing or dirt carried in with any metallic foreign body. It is a matter of common experience however, that the smaller, less irregular fragments are not as likely to be associated with such material. Indications for the removal of asymptomatic intrathoracic foreign bodies have not been entirely clarified. For several months shell fragments, 0.8 cm. or greater in diameter, were routinely removed from the pleural cavity, lungs, myocardium, and mediastinum. More recently it has seemed advisable to remove only those fragments which were not less than 1.5 cm. in diameter. Decision as to the proper time of removal is of great importance. There is considerable evidence that early thoracotomy (up to forty-eight hours) for the removal of intrathoracic foreign bodies is not justified in most instances. Morbidity, mortality, and postoperative infection rates are

much higher than when the operation is postponed. There is other evidence to suggest that after three to four weeks thoracotomy is somewhat more difficult. With the increased fibrosis present around intrapulmonary foreign bodies at that time repair and closure of the parenchymal incision are more uncertain. Extensive intrapleural adhesions of relatively firm fibrous tissue may increase the difficulty of adequately palpating the lung. Separation of these adhesions is not always easy.

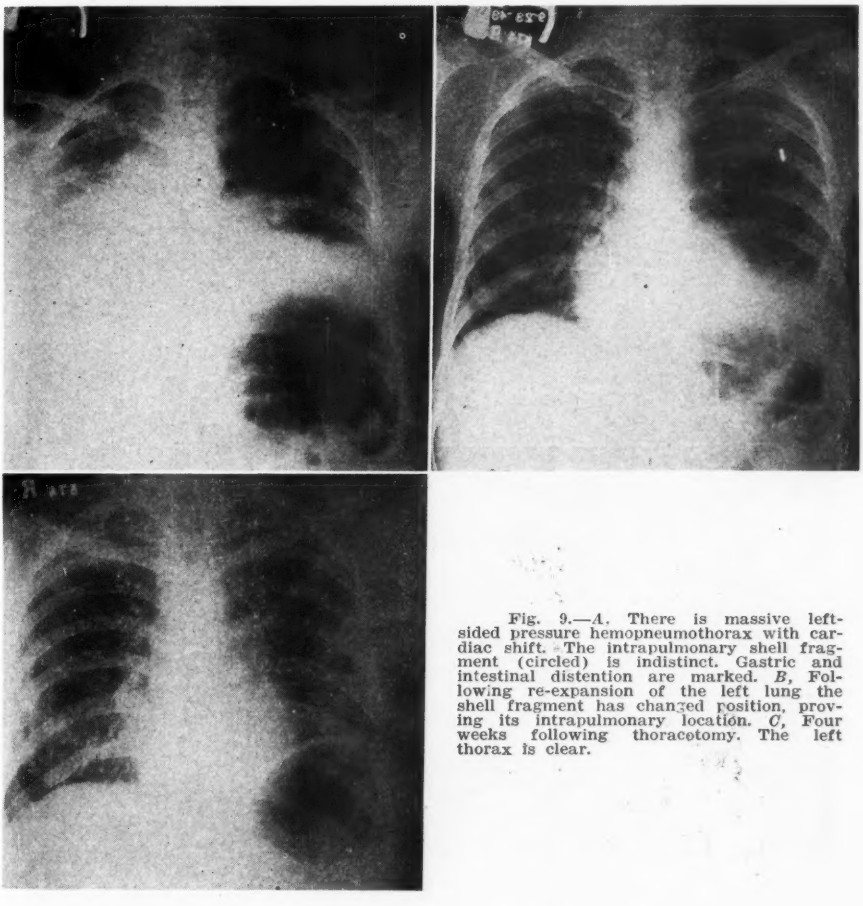
On the thoracic surgery service operations have been done up to twenty-five days following injury with but rare evidence of intrapulmonary infection. Preferably, however, thoracotomy is performed between the fourth and tenth days following injury. In most instances this gives adequate time for the secondary closure of wounds of the thoracic wall and for adequate pulmonary recuperation, both factors of the utmost importance in lowering the risk of operation. The elimination of granulating wounds from the thoracic wall prior to thoracotomy greatly reduces the hazards of infection. Pulmonary recuperation (recovery from the "traumatic wet lung" syndrome) entails reaeration of alveoli, absorption of interstitial fluid, re-establishment of complete tracheobronchial patency, and at least partial disposal of any extravasated intrapulmonary blood. The influence of these factors on mortality should be obvious. Technically, it is far easier to palpate metallic fragments in crepitant aerated pulmonary tissue than in a boggy indurated parenchyma. Furthermore, the lung is better able to sustain lobotomy if there has been some recovery from the initial injury.

For the most part, foreign bodies should be removed from the myocardium or pericardium. Usually, a transverse anterior approach gives the best exposure. If the removal is delayed too long, the difficulties of operation may be increased by the presence of fibrous tissue surrounding the shell fragment. Fear of erosion of the myocardium or of infection will dictate an early operation. It may be difficult to decide whether or not the myocardium should be sutured. When a cardiac chamber has not been perforated, there is evidence to show that this procedure may not always be necessary (Case 14).

The validity of removing asymptomatic shell fragments as a prophylactic procedure cannot be decided in a theater of operations. The final answer must come several years hence, from a determination of morbidity rates following operation, as compared to the percentage of complications which develop in patients with retained shell fragments.

CASE 9.—A British soldier, 29 years of age, sustained penetrating wounds of the left thorax and thigh from shell fragments during the landing operations at Salerno, Sept. 9, 1943. On admission to the thoracic surgery center three days later he was dehydrated, dyspneic, cyanotic, and greatly distended. Roentgenograms in the frontal and left lateral projection (Fig. 9*A*) showed left-sided pressure hemopneumothorax, cardiac shift, and compression of the right lower lobe. The left diaphragm was elevated and there was marked distention of the stomach and colon. An intrathoracic shell fragment was seen very indistinctly, lying at the level of the second anterior interspace. Immediate therapy consisted of thoracentesis of 900 c.c. of air and a small amount of dark blood, continuous Wangensteen suction, and injections of prostigmine. The immediate dramatic improvement testified to

the value of multiple concomitant treatments when necessary. Pulmonary inflation gave proof that the shell fragment was within the lung. In Fig. 9*B* the foreign body is seen to have moved upward and outward as the lung became expanded. Left-sided posterolateral thoracotomy was performed, September 24, fifteen days after injury. A moderate-sized organizing hemothorax was present and the thin layer of loosely adherent fibrin was easily stripped from the visceral pleura. The shell fragment was removed from the inferior border



A. *B.* *C.*

Fig. 9.—*A*. There is massive left-sided pressure hemopneumothorax with cardiac shift. The intrapulmonary shell fragment (circled) is indistinct. Gastric and intestinal distention are marked. *B*, Following re-expansion of the left lung the shell fragment has changed position, proving its intrapulmonary location. *C*, Four weeks following thoracotomy. The left thorax is clear.

of the upper lobe, and a small wedge resection performed on grossly necrotic lung in the same area. The cut surfaces of the wedge were approximated and the defect was repaired in two layers, using fine silk. The lung expanded completely on slight positive pressure and the thorax was closed in layers without drainage. The postoperative course was complicated by transient ileus and by early difficulties with adequate thoracentesis. The lung expanded completely, however, and the patient was evacuated to a British installation in excellent condition. In Fig. 9*C* is shown the status of the thorax four weeks following thoracotomy. The

pulmonary fields were completely clear. There was slight elevation of the left diaphragm and moderate gastric distention. The latter was asymptomatic at the time of discharge.

CASE 10.—A 24-year-old officer suffered a penetrating wound of the right thorax on Sept. 26, 1943. Three thoracenteses were done prior to his admission to the thoracic surgery service on October 6. At this time the roentgenograms (Figs. 10*A* and *B*) showed a small right-sided hemothorax and an intrapulmonary metallic foreign body, probably the jacket of a bullet. Sterile serosanguineous fluid was obtained by thoracentesis. Right-sided lateral

A. *B.*

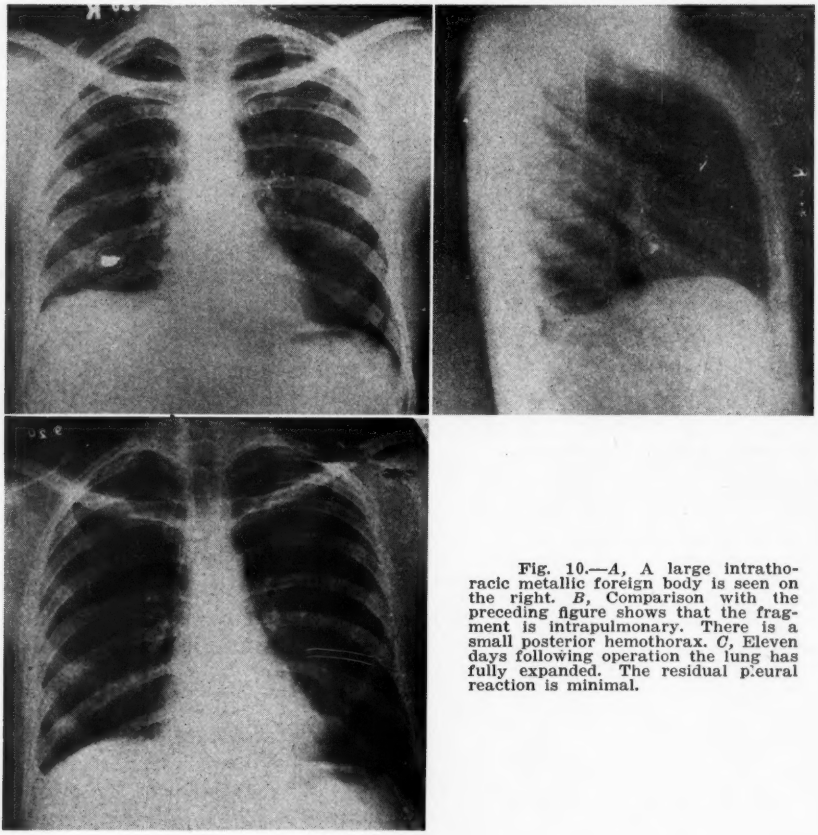
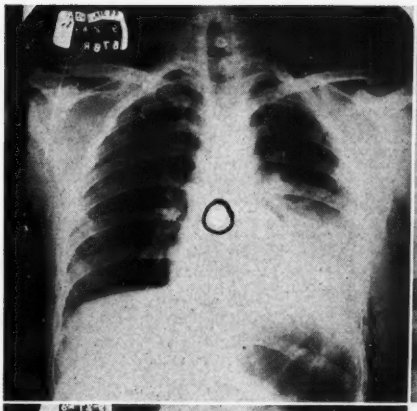


Fig. 10.—*A*, A large intrathoracic metallic foreign body is seen on the right. *B*, Comparison with the preceding figure shows that the fragment is intrapulmonary. There is a small posterior hemothorax. *C*, Eleven days following operation the lung has fully expanded. The residual pleural reaction is minimal.

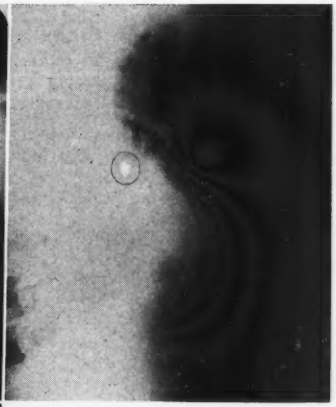
C.

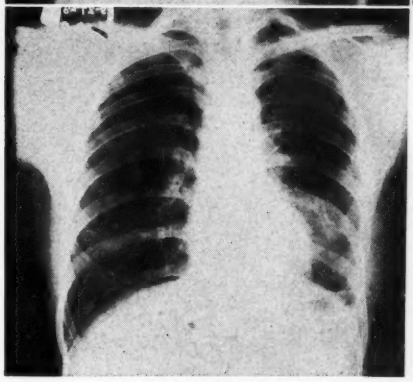
intercostal thoracotomy was performed on October 9, thirteen days after injury. The thorax was opened through a short incision in the sixth interspace without cutting a rib; the pleural cavity was dry. The metallic fragment was extracted from deep in the middle lobe and bits of adherent clothing were recognizable. Smears were negative for pus cells and organisms. The pulmonary incision was approximated in two layers with interrupted 000 silk and the thorax was closed without drainage. The lung expanded rapidly and a single thoracentesis was performed one week later. The patient was out of bed twenty-four hours following his operation and returned to full combat duty in three weeks. A roentgenogram taken eleven days postoperatively (Fig. 10*C*) showed complete pulmonary expansion and minimal pleural reaction.

A.



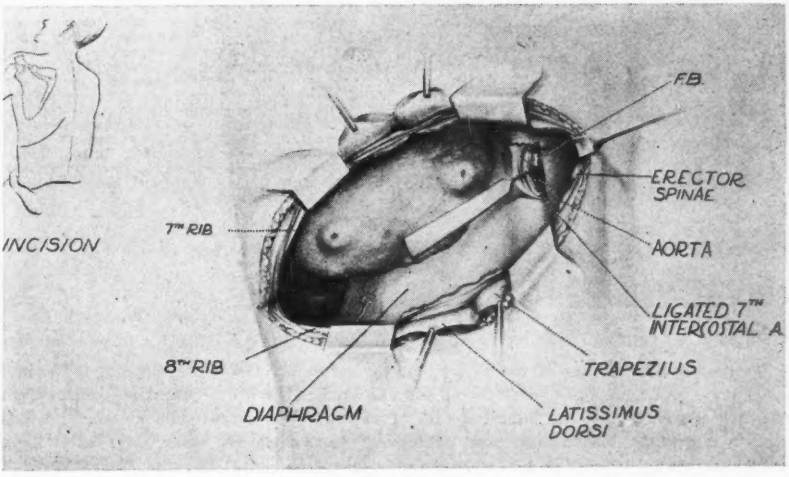
B.





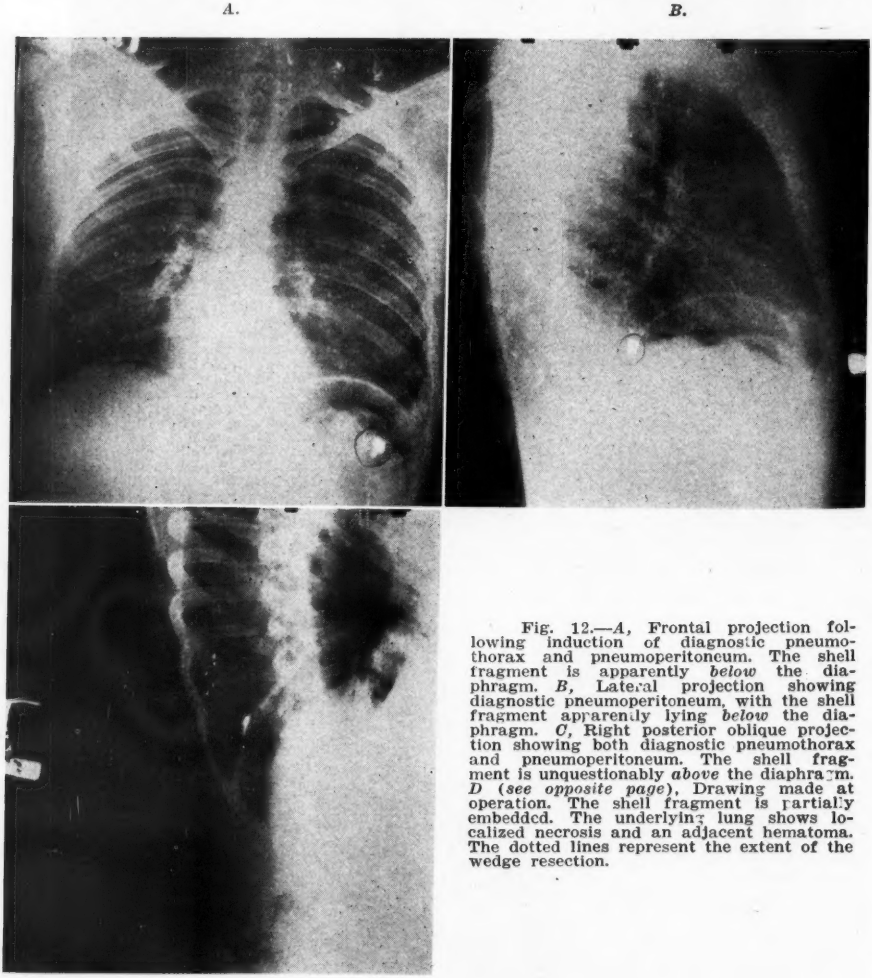
D.

Fig. 11.—*A*, There is a left-sided hemothorax. The poorly defined shell fragment lies exactly in the midline. *B*, The shell fragment is posterior and the hemothorax obscures the left lower lobe. *C*, Drawing made at operation. Two hematomas are visible on the surface of the left lower lobe. These are the points of entrance and exit of the perforating shell fragment. The latter has been visualized by partially mobilizing the aorta. It lies just to the right of and behind the aorta, between it and the esophagus. *D*, Eleven days following thoracotomy. The lung has completely re-expanded.



C.

CASE 11.—A 23-year-old British soldier was wounded on the Salerno beachhead, Sept. 9, 1943. He was admitted to the thoracic surgery center three days later where examination showed a penetrating shell fragment wound of the left thorax laterally. The patient was moderately dyspneic and was coughing up small amounts of old blood. The roentgenograms showed a left-sided hemothorax. In the frontal projection (Fig. 11*A*) a shell fragment, 14 by 10 by 8 mm., lies exactly in the midline; in the lateral projection (Fig. 11*B*) it is



A. *B.*

C.

Fig. 12.—*A*, Frontal projection following induction of diagnostic pneumothorax and pneumoperitoneum. The shell fragment is apparently *below* the diaphragm. *B*, Lateral projection showing diagnostic pneumoperitoneum, with the shell fragment apparently lying *below* the diaphragm. *C*, Right posterior oblique projection showing both diagnostic pneumothorax and pneumoperitoneum. The shell fragment is unquestionably *above* the diaphragm. *D* (*see opposite page*), Drawing made at operation. The shell fragment is partially embedded. The underlying lung shows localized necrosis and an adjacent hematoma. The dotted lines represent the extent of the wedge resection.

seen at the anterior border of the seventh dorsal vertebra. On September 13, thoracentesis yielded only 75 c.c. of thick, dark blood and the patient developed negative pressure symptoms. On September 14, the lateral wound of entrance was excised and closed. Left-sided posterior intercostal thoracotomy was performed, September 16, seven days after injury. The pleural cavity contained 600 c.c. of liquid blood and clot, but the pleura itself was

unchanged and there was no fibrinous organization. Two raised, purplish, indurated areas, 2 cm. in diameter, were seen on the surface of the lower lobe, one anterolaterally and one posteromedially (Fig. 11*C*). These were hematomas, caused by the passage of the shell fragment through the lower lobe. There was no leakage of blood or air on moderate positive pressure. A small tear was located in the parietal pleura just lateral to its reflection over the aorta. This was enlarged and the aorta mobilized by ligating the seventh intercostal artery. The shell fragment had passed posterior to the aorta between the sixth and seventh intercostal arteries and was found at the right border of the aorta posteriorly, between it and the esophagus. It was removed and the mediastinal pleura closed loosely. Five grams of sulfanilamide were placed in the pleural cavity and the usual layered closure with silk performed, using anterior and posterior intercostal drainage tubes. Immediate postoperative bronchoscopy was performed and a few bloody secretions were aspirated. The lung reexpanded completely within twenty-four hours. Fig. 11*D*, made eleven days postoperatively, shows the left lung filling the hemothorax and a minimal blunting of the costophrenic sinus. The patchy obscuration in the left lower lobe represents the residuum of the hematoma. This patient was presumably returned to full combat duty approximately ten weeks after injury.

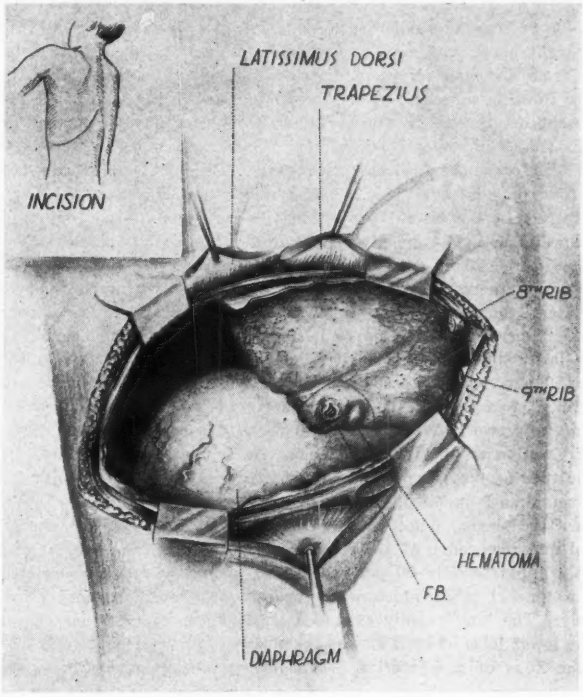


Fig. 12*D*. (*For legend see opposite page.*)

Case 12.—A 26-year-old soldier sustained a penetrating wound of the left posterior thorax on August 2, 1943. The patient coughed no blood but was dyspneic for a short time after injury. Roentgenograms showed a shell fragment in the region of the left diaphragm. Accurate localization was made possible by the use of induced pneumoperitoneum. Following this procedure roentgenograms were taken in the posteroanterior (Fig. 12*A*), the left lateral (Fig. 12*B*), and the right posterior oblique (Fig. 12*C*) projections. While apparently below the diaphragm in the frontal and lateral views, the oblique projection makes it certain that

the foreign body lies within the thoracic cavity above the diaphragm. On August 12, ten days after injury, the wound of entrance was first excised and closed using separate instruments. Left-sided posterior intercostal thoracotomy, with removal of the shell fragment and wedge resection in the lower lobe, was then performed. The shell fragment, 17 by 10 by 9 mm., had incompletely entered the lung at the periphery of the lower lobe posterolaterally and was surrounded by yellow fibrin and exudate (Fig. 12*D*). The underlying lung appeared necrotic, being boggy and purplish black in color. A small raised hematoma was adjacent. A wedge resection of the necrotic area in the lower lobe was done; the small bronchus and artery leading to the area were ligated and buried when the two surfaces of the wedge were sutured together. Ten grams of crystalline sulfanilamide were placed in the pleural cavity. Anterior and posterior intercostal water-seal tubes were used and the incision was closed in layers with interrupted silk. The anterior tube was removed in twenty-eight hours, and the posterior tubes in seventy-two. Ten days after injury the lung was completely expanded. The slightly increased pleural reaction at the base was probably due to the pulmonary resection. Microscopic sections of the lung showed localized necrosis and a hematoma, with evidence of early repair.

CASE 13.—A 24-year-old soldier sustained multiple penetrating shell fragment wounds of the thorax, right hand, calf, and upper abdomen on Oct. 13, 1943. A laparotomy was performed the same day and all wounds were débrided. Ten days later the patient was evacuated to the thoracic surgery center. The lower two-thirds of the right thorax presented flatness and absent breath sounds. Seven hundred cubic centimeters of very dark blood and clots were aspirated. Subsequently three aspirations were performed and 200 to 300 c.c. of dark clotted blood were obtained on each occasion. Fig. 13*A* and *B* was taken on November 6, twenty-four days after injury. There was a uniform hazy density involving the right lower thorax. In the lateral projection this was seen to be limited sharply to the region of the lower lobe. The density represented a localized organizing hemothorax. The shell fragment measured 23 by 6 by 3 mm. and was within the substance of the lower lobe. The seventh rib was fractured posteriorly. On November 13, thirty-one days following injury, a posterolateral thoracotomy was performed on the right side under endotracheal nitrous oxide-oxygen ether anesthesia. The upper lobe was well expanded. The pleurae were sealed off around the lower lobe and this cavity contained 250 c.c. of old blood and clot. The lower lobe was 50 per cent collapsed and held in this position by a firm organizing fibrin peel which was 3 mm. in thickness. This was removed by combined sharp and blunt dissection. Posterolaterally two rib fragments were found driven into the lower lobe. There was no evidence of reaction or repair about them. On removal there was bleeding and escape of air from the tear of the parenchyma. This was readily controlled with fine silk sutures. The shell fragment was found in the subapical portion of the lower lobe near the mediastinal surface. After the lobe was decorticated and completely freed, the shell fragment was easily identified and removed. At the conclusion of the operation the lung could be immediately expanded approximately 90 per cent. The pleural cavity was drained with anterior and posterior water-seal tubes which were removed on the second and third postoperative day, respectively. The lung rapidly expanded with almost complete clearing of the density surrounding the lower lobe. Fig. 13*C* was taken five days postoperatively. The patient was evacuated to the Zone of the Interior in excellent condition on December 1.

CASE 14.—A 31-year-old soldier was wounded in the left thorax by a high explosive shell fragment, Nov. 19, 1943. Two and one-half hours later, he arrived at a semimobile evacuation hospital in severe respiratory distress and coughing up blood. The pulse was 140, respirations 20, and blood pressure, 130/80. There was a wound in the left ninth intercostal space posteriorly and signs of fluid in the left lower thorax. Roentgenograms revealed a shell fragment in the cardiac region near the diaphragm, a compound comminuted fracture of the ninth rib, and intrapleural fluid. The shock treatment consisted in the intravenous administration of two units of plasma and oxygen per nasal catheter. The possibility of diaphragmatic perforation, and injury to a viscus in the left upper quadrant of

the abdomen, made exploration mandatory although abdominal signs were not prominent. Because of ease of exposure the transdiaphragmatic approach was used. The wound in the thoracic wall was débrided and fragments of the ninth rib were removed. The incision was extended to permit adequate exposure of the diaphragm which was found to be torn in its mid-portion. After opening the diaphragm widely, a small laceration of the left lobe of the

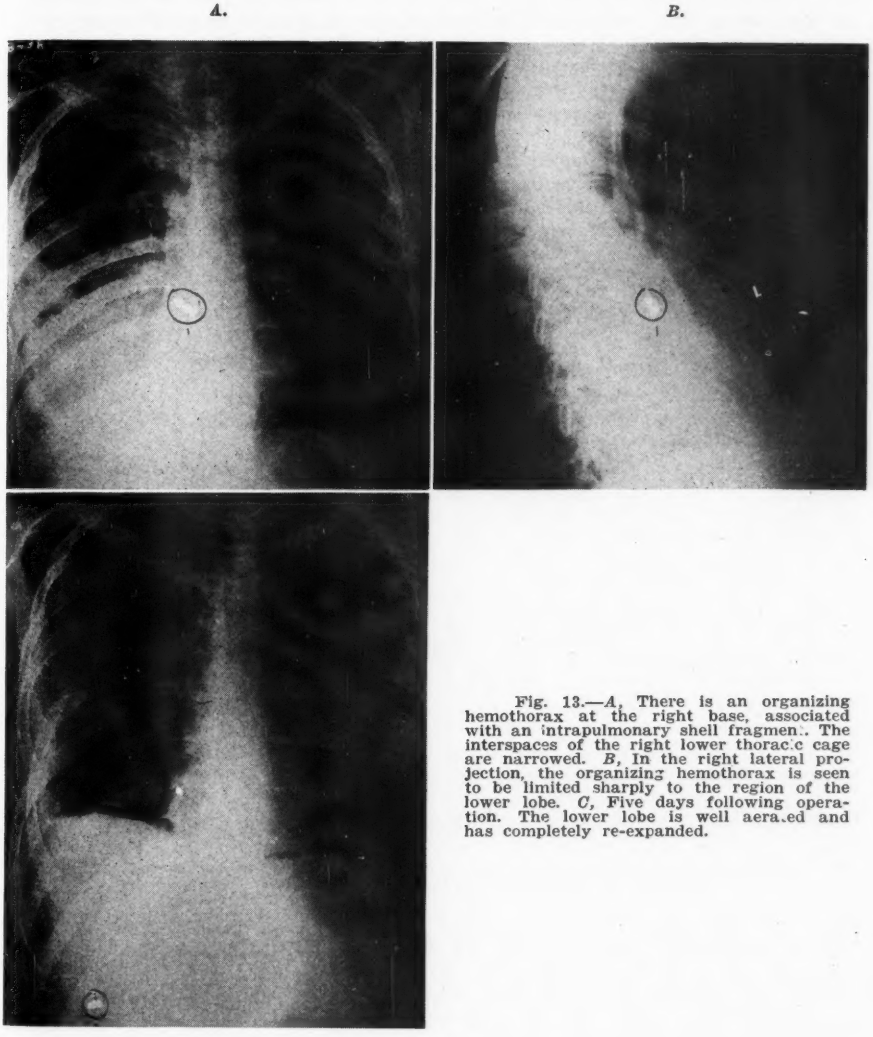


Fig. 13.—*A*, There is an organizing hemothorax at the right base, associated with an intrapulmonary shell fragment. The interspaces of the right lower thoracic cage are narrowed. *B*, In the right lateral projection, the organizing hemothorax is seen to be limited sharply to the region of the lower lobe. *C*, Five days following operation. The lower lobe is well aerated and has completely re-expanded.

liver was noted but there was no other injury to the abdominal viscera. The diaphragm was closed with interrupted silk. Small intrapulmonary hematomas of the left lower lobe and lingula of the left upper lobe were present. By reaching upward and forward a metallic foreign body was felt embedded in the myocardium on the anterolateral surface of the left

ventricle. Since it was impossible to obtain adequate exposure of the heart through the low posterior incision, this wound was closed. Although 500 c.c. of blood had been given during the operation and the blood pressure was 112/54, the patients pulse was 130, weak and irregular. His condition was not good enough for further immediate surgery and he was, therefore, returned to the ward.

Since the pericardium was widely torn, cardiac tamponade was not feared. However, decision was made to remove the foreign body as soon as the patient's condition permitted, because of the danger of erosion of the myocardium, further bleeding, and infection. A roentgenogram taken forty hours after the thoracic laparotomy showed that the shell fragment had not changed its position, and thoracotomy was deemed advisable. Since the pericardium was known to be in communication with the pleura, transpleural approach through a transverse incision in the fourth intercostal space was elected. The fourth and fifth cartilages were severed and the anterolateral surface of the heart exposed. About two-thirds of the way to the apex, lateral to the anterior descending branch of the left coronary artery, the foreign body was seen imbedded in the myocardium (Fig. 14). The shell fragment was grasped with a hemostat and very gently moved. No hemorrhage occurred and the foreign

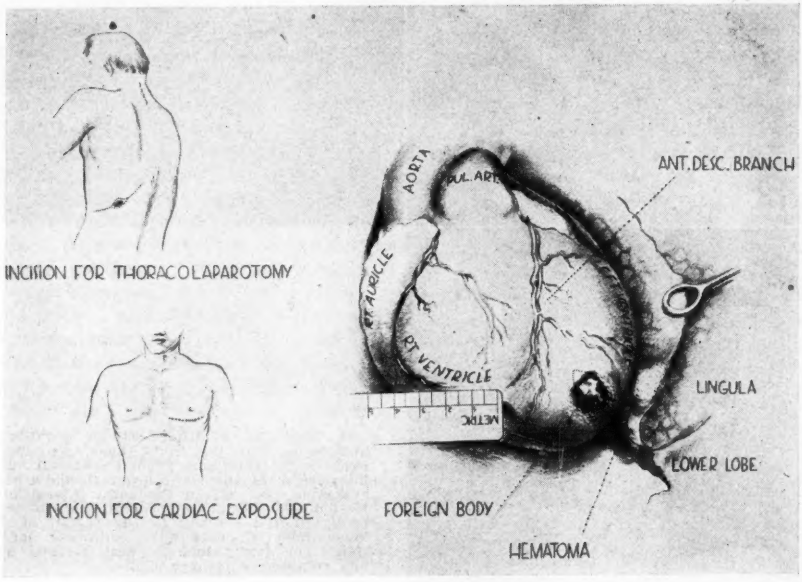


Fig. 14.—Drawing made at operation. The irregular shell fragment has partially embedded itself in the myocardium of the left ventricle near the apex.

body was very slowly removed. A piece of clothing 1 cm. in diameter driven into the myocardium was also extracted. There was no bleeding from the heart muscle. Since for a distance of ½ cm. on each side of the defect the myocardium was ragged and necrotic looking, any attempt to suture the edges would mean incorporating more than 2½ cm. of myocardium in the suture. Such a suture might set up nervous impulses leading to ventricular fibrillation and certainly would produce ischemia over this area of the myocardium. After watching this traumatized area of the myocardium twenty minutes, no hemorrhage or bulging was noted. We estimated that several millimeters of myocardium were present at the depth of the ventricular defect. It was then decided not to attempt suture of, or reinforcing muscle graft to, the myocardium. The pericardium was left open to permit drainage into the pleural cavity. The chest wall was closed in layers without drainage. The

postoperative course was uneventful. In general he was treated like a patient with coronary occlusion. Fluids were restricted to 2,000 c.c. per day. Four grams of sulfadiazine were administered daily until the third week after operation when he had some renal pain. From time to time he showed irregularities of the pulse in the form of extra systoles and dropped beats. After the aspiration of 270 c.c. of serosanguineous fluid from the left pleural cavity, the left lung was expanded. No evidence of myocardial aneurysm was present. Electrocardiographic tracings demonstrated signs of myocardial infarction of the left ventricle but no irregularities of rhythm. He was continued on bed rest and evacuated to the Zone of the Interior. No evidence of myocardial aneurysm was noted two months after the injury. This would seem to justify our decision that suture of the myocardium or placing of a muscle graft on the defect was not indicated. After operation these patients should be treated like those convalescing from coronary occlusion.

CONTINUED INTRAPLEURAL HEMORRHAGE

Continued intrathoracic hemorrhage constitutes one of the indications for a relatively early thoracotomy. In common with many other reports, however, Case 15 illustrates that adequate time may usually be taken for thorough study and preparation of the patient. The source of bleeding has usually been from the intercostal or internal mammary vessels. Severe hemorrhage from the lung itself has been rarely seen, even in the forward medical installations.

CASE 15.—A 23-year-old soldier sustained an accidental penetrating gunshot wound of the left thorax on July 27, 1943. He was evacuated by air without difficulty. On admission to the thoracic service twenty-four hours later, he was moderately dyspneic. Physical examination confirmed by roentgenograms revealed a left-sided tension hemopneumothorax with shift of the heart to the right. A small caliber bullet was present in the deep muscles of the back near the tenth dorsal vertebra. On July 29, dyspnea was relieved by the aspiration of 450 c.c. of air and the lung was felt touching the needle. Later the same day, further dyspnea was completely relieved by the aspiration of 1,000 c.c. of air and 250 c.c. of bright red blood anteriorly. Again, the lung was felt touching the needle. On July 30, the patient felt something "give way" in his chest and he rapidly became dyspneic for a third time. Examination showed that the mediastinal shift had returned and an increase of fluid was present. Thoracentesis was performed in the second anterior interspace, with the removal of 700 c.c. of air under moderate pressure and a small amount of bright red blood. The patient was transfused for immediate thoracotomy because of the evidence of persisting hemorrhage and leakage of air. The operation was performed seventy-two hours after injury.

Under endotracheal anesthesia a posterolateral incision was made and the pleural cavity entered through the seventh interspace. The air in the pleural cavity was under slight positive pressure; 600 c.c. of fresh unclotted blood were evacuated. An area of lacerated lung was found at the edge of the pulmonary ligament near the lower margin of the inferior pulmonary vein. It continued to ooze fresh blood and bubbles of air on the administration of slight positive pressure. Compression of the lung could have had only a minimal effect on this area. A small anomalous blood vessel lying mesially between lung and diaphragm was also lacerated and bleeding. The bullet also caused a superficial laceration of the diaphragm. All areas were repaired with fine silk. The thorax was closed airtight without drainage and the lung expanded by the aspiration of air. Convalescence was uneventful; a total of 750 c.c. of bloodstained serum and 300 c.c. of air were aspirated during the first eight days. At the time of evacuation, four weeks following surgery, a roentgenogram showed moderate diaphragmatic elevation. The lung was well aerated and there was a slight residual pleural reaction at the base. A small lateral pneumothorax pocket persisted.

SUMMARY AND CONCLUSIONS

The advisability of forward thoracic surgery centers in a theater of operations has been emphasized. Special traumatic surgical problems which were

encountered in a thoracic surgical center have been presented. These problems have been discussed in broad terms and the methods of their solution have been enumerated. Details of surgical therapy have been given. The indications for the removal of intrathoracic metallic foreign bodies have been presented. Based on studies of the pathogenesis of intrapleural hemo-organization, the use of early pulmonary decortication has been stressed, in dealing with uncontaminated organizing hemothorax, infected hemothorax, and hemothoracic empyema.

ACKNOWLEDGMENTS

The authors acknowledge their indebtedness to the officer, nurse, and enlisted personnel of their respective teams. Much of this work would not have been possible without the continued wholehearted cooperation of our associates. We are indebted to Sergeant Walter Meigs, a member of one of our teams, and to Sergeant Hooker Goodwin of a Museum and Medical Arts Detachment for the excellence of the illustrative drawings in this paper. Members of the Signal Corps and of the Army Pictorial Service are jointly responsible for the reproduction of the roentgenograms.

A REVIEW OF THE ACTIVITIES OF THE THORACIC CENTER FOR THE III AND IV HOSPITAL GROUPS, 160th GENERAL HOSPITAL EUROPEAN THEATER OF OPERATIONS, JUNE 10, 1944, TO JAN. 1, 1945*

LIEUTENANT COLONEL DWIGHT E. HARKEN, MEDICAL CORPS,
ARMY OF THE UNITED STATES

SHORTLY before D Day, it was ordered that arrangements be made for establishing a thoracic center in the 160th General Hospital and a chief of the thoracic section was assigned.

The professional activities of the hospital at that time were minimal, so it was possible to select and train ward and operating personnel for a period of a few weeks. A series of lectures was given to the nurses who showed an interest in chest surgery.

The first patient was a sergeant in the Air Corps, who had been injured over Germany. He had been under care in various hospitals for treatment of an infected hemothorax. This infected hemothorax had long since become a chronic empyema. The patient became a charge of this general hospital when it arrived. A rib resection drainage was performed to provide more adequate drainage and constituted the first "chest center" operation in the European Theater of Operations.

On D Day plus four, chest casualties began to come in, and since that time 982 patients have been treated as direct admissions to the thoracic unit or as patients assigned to other departments, but also suffering concomitant chest injuries.

PERSONNEL

The personnel of the group has varied considerably. The only members of the organization who have served throughout are the chief of the section, the senior ward nurse, two of the surgical nurses, and the chief anesthetist. This nucleus has been variously and ably augmented by members of the medical and surgical services, as well as an extremely competent team from the First Auxiliary Surgical Group.

THE FUNCTION OF THE CHEST CENTER

Five per cent of the casualties coming to the United Kingdom Base Section suffered from major thoracic injuries. These injuries were distributed roughly as shown in Table I.

Twenty per cent of the major thoracic injuries needed special care in a thoracic center. The distribution of the bulk of the thoracic surgical treatment of this center can best be outlined in terms of the operations performed and the mortality rates obtained (see Table II).

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*Policies and case distribution remained essentially the same from January, 1945, to July, 1945.

TABLE I. DISTRIBUTION OF PATIENTS WITH CHEST INJURIES ADMITTED TO GENERAL HOSPITALS IN THE UNITED KINGDOM BASE SECTION

Hemothorax			70%
Unclotted		60%	
Infected	3%		
Uninfected	57%		
Clotted		10%	
Infected	4%		
Uninfected	6%		
Retained foreign bodies			15%
Requiring surgical removal		8%	
Thoracoabdominal wounds			8%
Hematoma of the lung			4%
Injuries of the heart and pericardium including retained foreign bodies			3%

Twenty per cent of this group were referred to thoracic surgical centers.

Five patients who had had rib resection drainage of empyema died of associated injuries. None of these deaths were due to empyema or operation.

In the tabulation of major thoracotomies, in which rib resection drainage is not included, there were over 400 operations with 2 surgical deaths, a mortality rate of less than one-half of 1 per cent. In the 982 admissions there were 9 deaths, a service mortality rate of less than 1 per cent.

POLICIES IN TREATMENT

This survey does not permit detailed discussion of all types of cases. It must suffice to outline briefly the policies that have evolved in the treatment of certain lesions. An effort is being made by the members of this organization to present these various subjects in greater detail.

Hemothorax.—While few of the hemothoraces are actually dealt with in this center, the importance of the problem demands a statement of therapeutic policy. Treatment consists of *complete aspiration and breathing exercises.*

TABLE II. DISTRIBUTION OF THE PRINCIPAL TYPES OF SURGICAL PROCEDURES, WITH MORTALITY RATES

SURGICAL PROCEDURE	NUMBER	DEATHS	MORTALITY RATE (PER CENT)
Removal of foreign bodies	247*	1	0.4
Lung	162	0	0
Mediastinum	22	1	4.5
In or in relation to the heart	32	0	0
(chambers of heart)	9	0	0
In or in relation to great vessels	7	0	0
Diaphragm	10	0	0
Subphrenic area	14	0	0
Pleural space	31	0	0
Decortications	112	1	0.9
Uninfected clotted	64		
Infected clotted	48		
Thoracoabdominal operations	35	0	0
Liver abscess	11	0	0
Subphrenic abscess	10	0	0
Hepatobronchial fistula	8	0	0
Diaphragmatic hernia	6	0	0
Lobectomy (including partial)	15	0	0
Repair of injuries to major vessels	5	0	0
Rib resection drainage of empyema	91	5	5.5

*Discrepancy due to subgroup overlap.

The unfortunate sequelae of inadequately treated hemothorax are (1) empyema, (2) reduced pulmonary function, (3) late pulmonary suppuration, and (4) body deformity. The misfortunes are reduced to a negligible figure if aspiration and breathing exercises are instituted. A word of explanation is in order regarding "specific remedial breathing exercises," which refers neither to the use of "blow bottles" nor to calisthenics. Specific remedial breathing exercises are aimed at the acquisition by the patient of an ability to control voluntarily the unilateral and segmental respiratory activity of a poorly functioning region of the thorax. The importance of this subject demands a special section in this interval report.

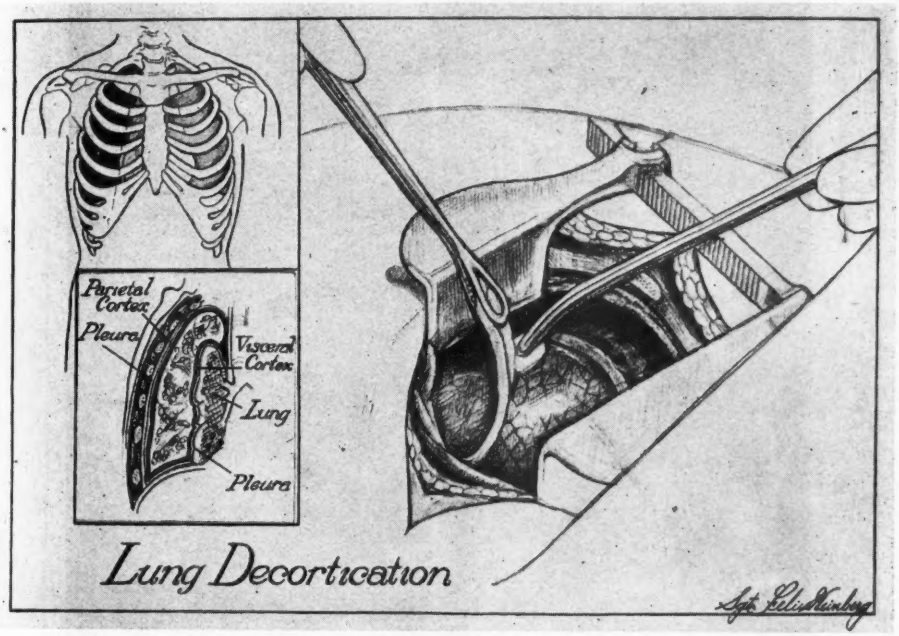

Fig. 1.—Insets illustrate the extent of the cortical bag and sagittal section thereof with connective tissue walls incarcerating the collapsed lung. Loose debris of broken-down blood elements are shown between the cortical walls.

Technique of decortication is illustrated in the large diagram. The visceral cortex is being peeled off the normal underlying lung.

Clotted Hemothorax.—In approximately 10 per cent of hemothoraces, clotting is a problem. A clinically significant cortex that incarcerates the lung in a collapsed state occurs in less than one-half of these. Burford and Samson of the United States Army and Nicholson of the British Army have pointed out the useful operation of decortication for dealing with this condition (see Fig. 1). The cortices, or membranes, are well-organized connective tissue walls varying from a few millimeters to 2 cm. in thickness. They have a mesothelial surface that is in contact with the pleura. This membranous cortex constitutes a bag

that lies in the pleural cavity and is filled with the debris of broken-down blood elements. Removal of the constricting membrane is essential to permit expansion of the incarcerated lung. Before resorting to decortication in uninfected hemothoraces, the patients are observed for at least two weeks. During this time they practice vigorous breathing exercises for ten minutes of every hour. Repeated attempts at aspiration are made. Surgical intervention is postponed as long

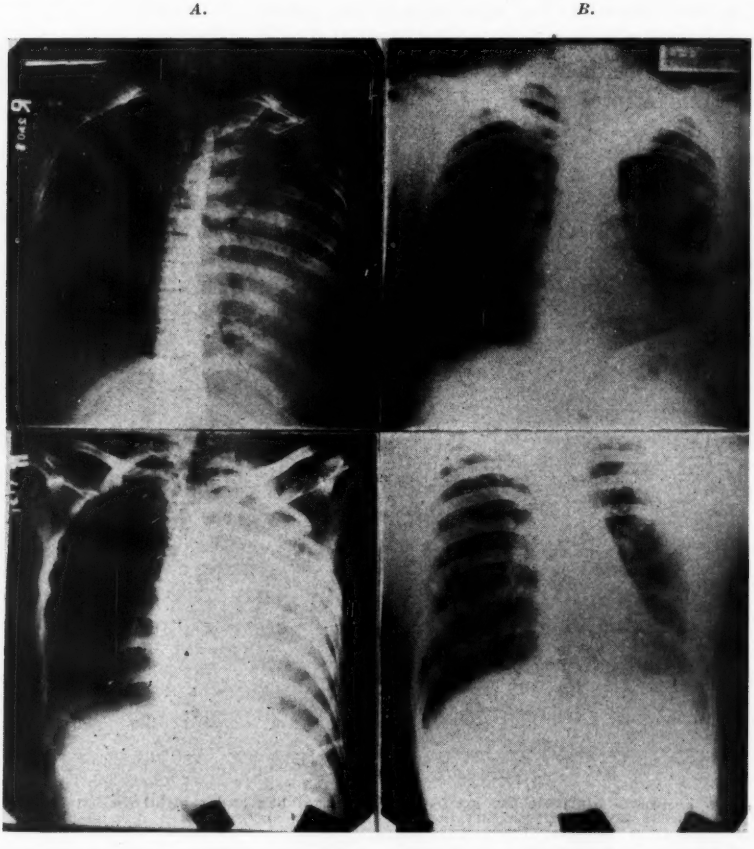

Fig. 2.—*A*, A solidly clotted vacuolated left hemithorax infected with *Clostridium welchii* and *Staphylococcus aureus*. *B*, Same patient three weeks after decortication with an essentially clear left hemithorax and fully expanded left lung. *C*, A solidly clotted hemithorax infected with *Bacillus coli*. *D*, Same patient three weeks after thoracotomy.

as the deformity of the "fused chest," mobility of the costal cage and diaphragm, and the cortical shadow are improving. Fluoroscopic examination is an essential part of this assessment. Decortication has been necessary in only sixty-four of these cases. In the event of bacterial contamination, or in the presence of a large foreign body, decortication need not be delayed.

There have been forty-eight decortications of contaminated clotted multiloculated hemothoraces. Approximately one-third had one or more pockets con-

taining pus. Decortication was the definitive operation with no subsequent empyema in more than 75 per cent of them. In those that developed subsequent empyema, it was of simple unilocular nature and responded well to the conventional open drainage by rib resection. These empyemas were usually caused by bronchopleural fistulas (see Fig. 2).

A small group of the patients with clotted hemopneumothorax have presented signs of acute cardiorespiratory embarrassment, overwhelming sepsis, or both. The loculation and clotting in the hemopneumothorax made relief by

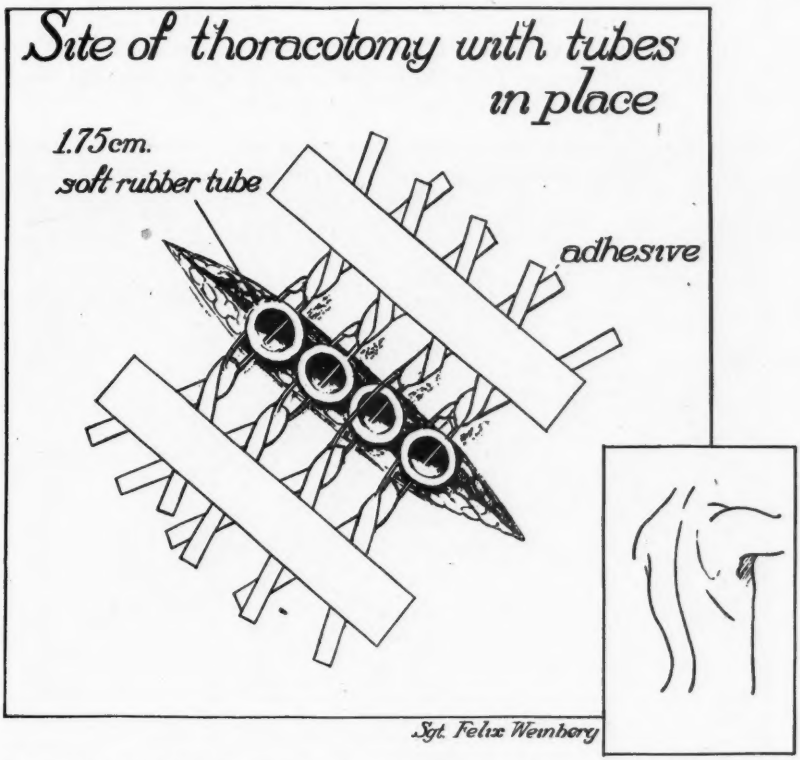

Fig. 3.—This illustration demonstrates the extensive nature of the rib resection drainage and the mechanism of tube stablization with adhesive that is advocated by this clinic.

aspiration impossible. For the same reason rib resection drainage of the infected hemopneumothoraces fails. Open thoracotomy with decortication, reexpansion of the lung, and closure of the chest wall, has been the only satisfactory treatment. The urgency of this condition and its prompt response to decortication have led us to become sensitive to this clinical syndrome as a thoracic surgical emergency.

The indications for decortication have been clear in the very large or total multiloculated and infected clotted hemopneumothorax. Smaller infected hemo-

thorax has been treated by rib resection drainage. We have felt that the infected clotted basilar hemothorax of a size estimated at less than 500 c.c. does not justify decortication.

Empyema.—Ninety-one rib resections have been performed for the treatment of infected hemothorax or empyema, as contrasted with forty-eight decortications. Our policy in the treatment of empyema is based upon four major premises:

1. Early adequate drainage. The dependent site is selected by study of x-ray views, by aspiration, and by the instillation of radiopaque oil (see Fig. 3).

2. General and specific remedial exercises are regarded as essential. The ambulatory treatment has made a great improvement in our results and even greater benefits have accrued from the intensive use of specific remedial breathing exercises with local activity of the involved thoracic region.

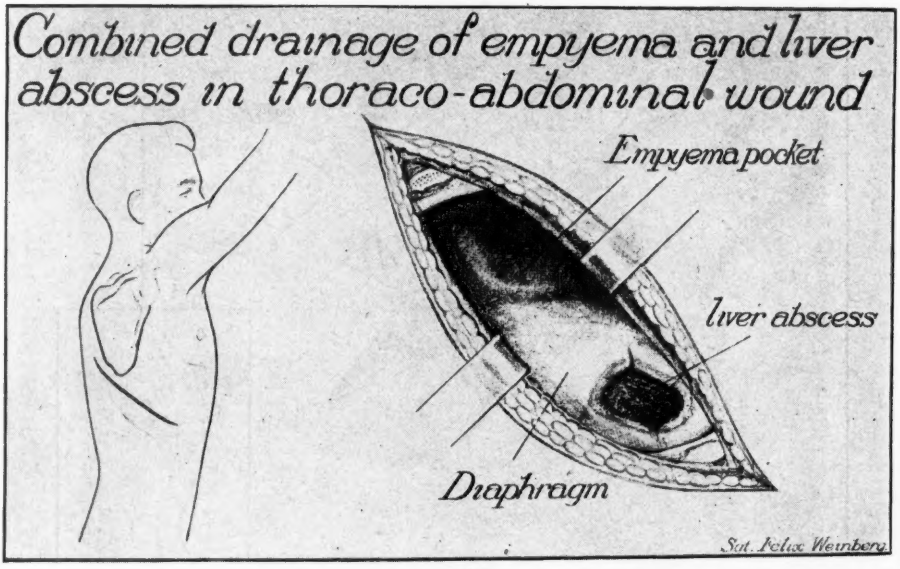

Fig. 4.—Thoracotomy by rib resection for drainage of empyema and transphrenic deroofing of subjacent suppurative process as advocated in this clinic.

3. The empyema cavity wall must be maintained in the acute inflammatory state in order that obliterative pleuritis will proceed rapidly. Whenever the pleural surfaces bear subacute or chronic inflammatory reactions, the walls become rigid and hyalinized and even, in time, calcified. The frequent application of irritating packs tends to maintain the desired acute pleuritis.

4. The nutritional state of the patient must be maintained. Appropriate diet, accessory vitamin therapy, and supplemental plasma and whole blood transfusions are useful in this part of the therapeutic program.

Thoracoabdominal Wounds.—There have been thirty-five thoracoabdominal wounds treated surgically. The management of the left-sided thoracoabdominal wounds has not presented a problem.

The transthoracic approach to diaphragmatic hernia has been universally used.

Twenty patients with right-sided wounds had liver abscesses associated with empyema. Five had biliary-bronchial fistulas. The empyemas were drained by rib resection thoracotomy. The subphrenic or liver abscesses were at the same operation drained into the empyema cavity by incision of the diaphragm (see Fig. 4).

Removal of Foreign Bodies.—Certain foreign bodies in the lungs are removed principally to prevent hemorrhage and suppurative processes. Factors influencing the decision to remove a foreign body from the lung are (1) size and irregularity, (2) proximity to major vessels or bronchi and dependent position in the parenchyma, and (3) surrounding reaction, clinical or roentgenologic.

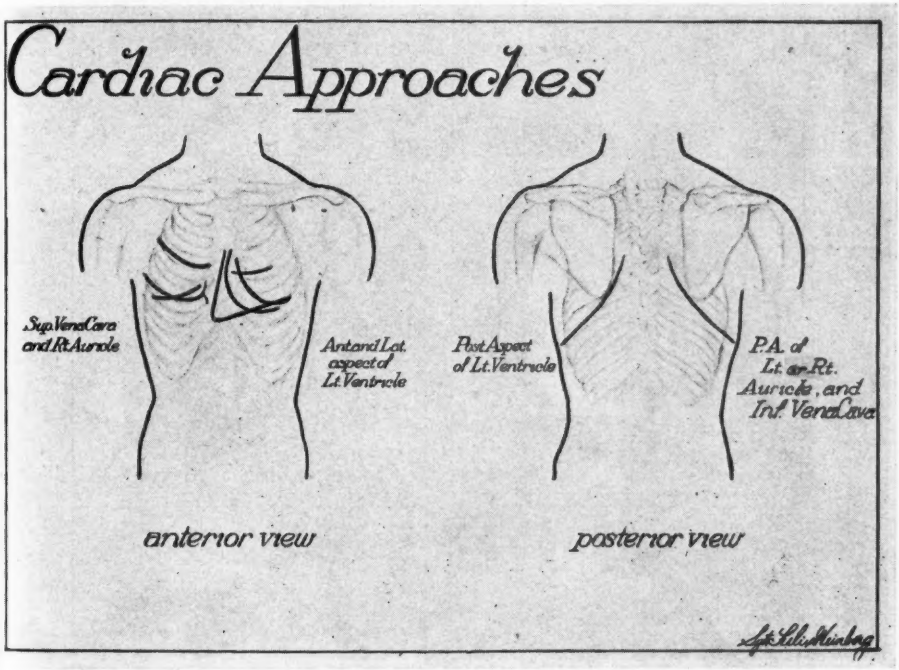
Cardiac Approaches
Sup. Vena Cava and Rt. Auricle
Ant. and Lat. aspect of Lt. Ventricle
Post. Aspect of Lt. Ventricle
P.A. of Lt. or Rt. Auricle, and Inf. Vena Cava
anterior view
posterior view

Fig. 5.—The approach is directed to the individual foreign body position.

It has been felt that even silent parenchymal foreign bodies greater than 1.5 cm. in two dimensions should be removed when the proper clinical facilities for such removal are available. The fact that these people are up and about in a matter of twenty-four to forty-eight hours and the fact that 162 such missiles have been removed with no deaths suggest that the policy outlined is reasonable. An essentially similar attitude is held toward foreign bodies in the mediastinum, pleura, and diaphragm.

It is interesting that pathogenic bacteria can be grown from 85 per cent of the intrathoracic foreign bodies removed, but in over 200 thoracotomies for the removal of such missiles only two empyemas have occurred.

Cardiac Foreign Bodies.—We have felt that certain foreign bodies in the heart should be removed (1) to prevent embolus (of the foreign body or of the associated thrombus), (2) to reduce the danger of bacterial endocarditis, (3) to

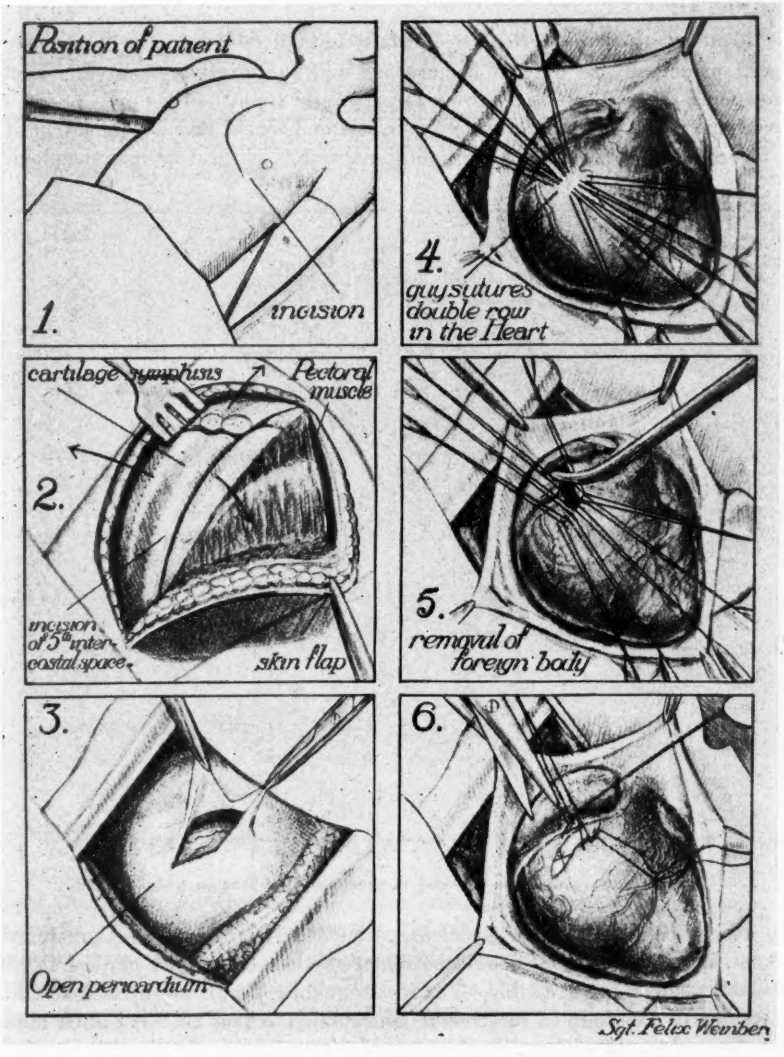

Fig. 6.—Diagrammatic representations of the principles involved in the hemostatic removal of intracardiac foreign bodies, without the interruption of the blood flow.

prevent recurrent pericardial effusions, and (4) to diminish the incidence of myocardial rupture or hernia.

Parenthetically the foreign body removal may be important in the correction of cardiac neuroses. The principal question remaining is whether such surgery can be carried out without a prohibitive mortality. Thirty-two foreign bodies that were in or on the heart have been removed; nine of these were in the chambers of the heart. The accompanying diagrams illustrate the approaches (Fig. 5), the technique of elective cardiotomy (Fig. 6), and the locations of some of the foreign bodies removed (Figs. 7 and 8). No deaths have occurred in this group. The patients have been rendered clinically well.

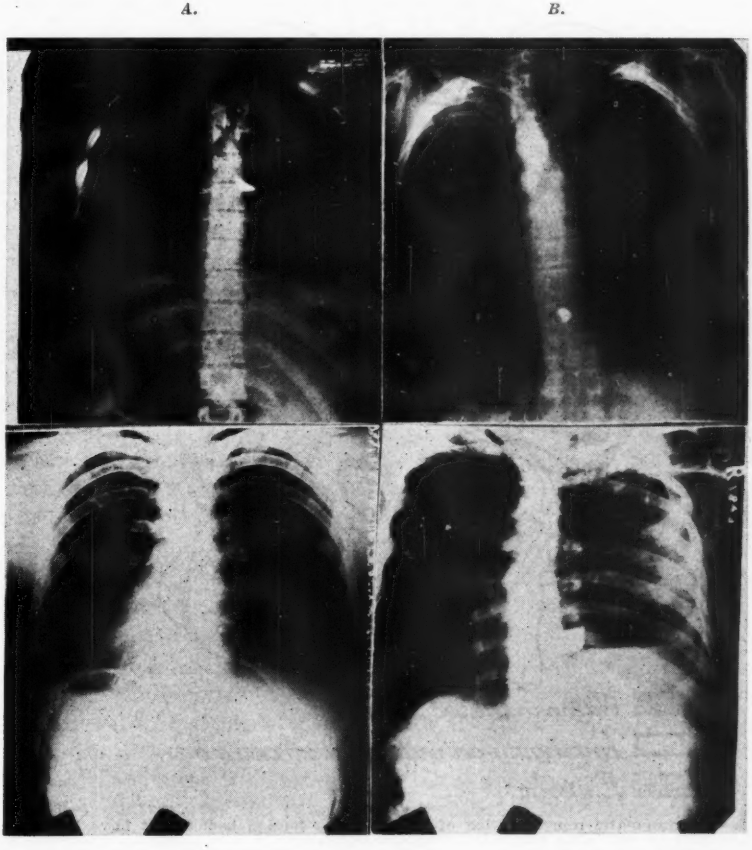

Fig. 7.—Roentgenograms of typical cardiac foreign bodies as viewed in the posterolateral position. *A*, Foreign body in right auricle. *B*, Foreign body in right ventricle and interventricular septum removed by sternal splitting approach. *C*, Right ventricular foreign body surrounded by myocardial and intraventricular abscess. *D*, Massive right intra-auricular foreign body.

REMEDIAL BREATHING EXERCISES IN THE TREATMENT OF CHEST INJURIES

Breathing exercises have been prominently mentioned throughout this survey. It may be well to give more detailed attention to the subject, as it was the privilege of this unit to convey this form of treatment to the American medical profession from the British.

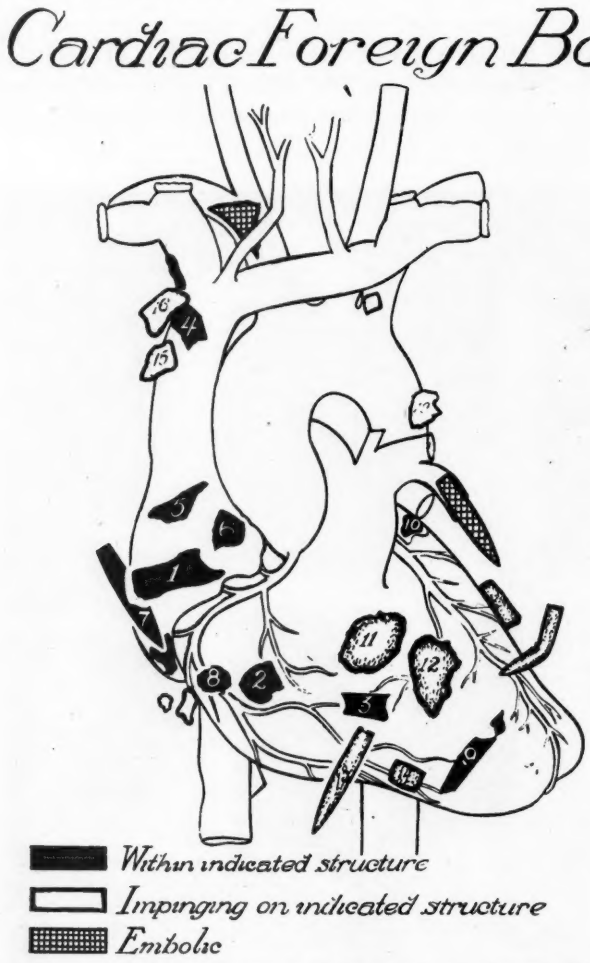

Fig. 8.—Diagrammatic representation of a few of the foreign bodies that have been removed in this clinic.

The mortality rate in traumatic thoracic surgery has now been reduced to a point where it compares favorably with those of appendectomy and herniorrhaphy. In view of present thoracic surgical standards, mortality rates cease to be adequate measuring sticks of the results in this field. One must now evaluate

thoracic surgery in terms of how quickly the patients are cured. It is fair to say that one of the most valuable contributions to the field of thoracic surgery in recent years has been the understanding and use of remedial breathing exercises. We are indebted to our British colleagues for this therapeutic aid.*

The "fused chest" following thoracic disease and producing the "pulmonary cripple" has become an unusual tragedy rather than the hallmark of thoracic surgery. The lung underlying a fused chest is now known to be virtually without function and prone to be involved in the gamut of suppurative processes. In assessing this parenchymal function of these crippled lungs, bronchospirometry has given an objective mechanism of determination. Jacobaeus, Wright, Cournand, Lester, and others have provided and perfected this method of study.

At the risk of oversimplification it may be well to present a practical rationale for this system of remedial breathing exercises, as this is useful in training the patient and in obtaining his essential cooperation in the program. Such a rationale runs as follows. At the time of injury or operation the chest wall becomes painful on motion and is splinted. Normally the voluntary and involuntary breathing mechanism is symmetrical but when splinted to avoid discomfort the involved side is divorced from the respiratory act. After a short period the automatic neuromuscular mechanism is interrupted and often does not return spontaneously. Frequently this immobilization by neuromuscular interruption is mechanically reinforced and, or, maintained by adhesions between the parietal and visceral pleura. The parietes and the lung may even be solidly incarcerated by the dense fibrous cortices. At this point the classical deformity may be noted (see Fig. 9). The head is moved laterally toward the injured side; the shoulder of the involved side slides downward and inward and moves medial to the vertical line from the anterior superior iliac spine. The chest wall assumes a position of full expiration. These changes are concomitant with the scoliosis and tilting of the pelvis demonstrated in Fig. 9. In short, the full picture of the fused chest or pulmonary cripple can be observed.

To insist that the patient "use the injured side of his chest" is quite futile for it has been lost to his motor cortex. Both involuntary and voluntary use of the affected side are gone.

Restoration of function begins with familiarizing the patient with his deformity. He is straightened in bed. He must have his pelvis returned to the normal position so that his weight is equally distributed on the two buttocks. His shoulders are next squared and the head is shifted to the midline. This overcomes the scoliosis. However, nothing has as yet been done about restoring motor cortex control over the muscles of respiration. Individuals do not exercise voluntary control over the independent respiratory activity of one side of the chest, much less the control of particular segments within one or the other hemithorax, yet this is precisely the thing required before recovery of therapeutic value can be expected. This establishment of voluntary motor control over

*Specific credit must be given the thoracic surgeon, Mr. A. Tudor Edwards, F.R.C.S., and his physiotherapists, the Misses Linton and Reed.

the injured hemithorax, and furthermore the voluntary motor control over the fused sunken segments of the injured hemithorax, is the foundation of successful remedial breathing exercises. Similarly, voluntary motor control over the excursions of the diaphragm is essential to the remobilization of that structure.

In the previous paragraph the necessity for voluntary respiratory muscle control has been emphasized. The problem then becomes one of educating the motor cortex or more properly the whole neuromuscular mechanism to voluntary control of areas not normally under the voluntary domain (in the fused chest dropped even from the normal involuntary sphere). As demonstrated in Fig. 9

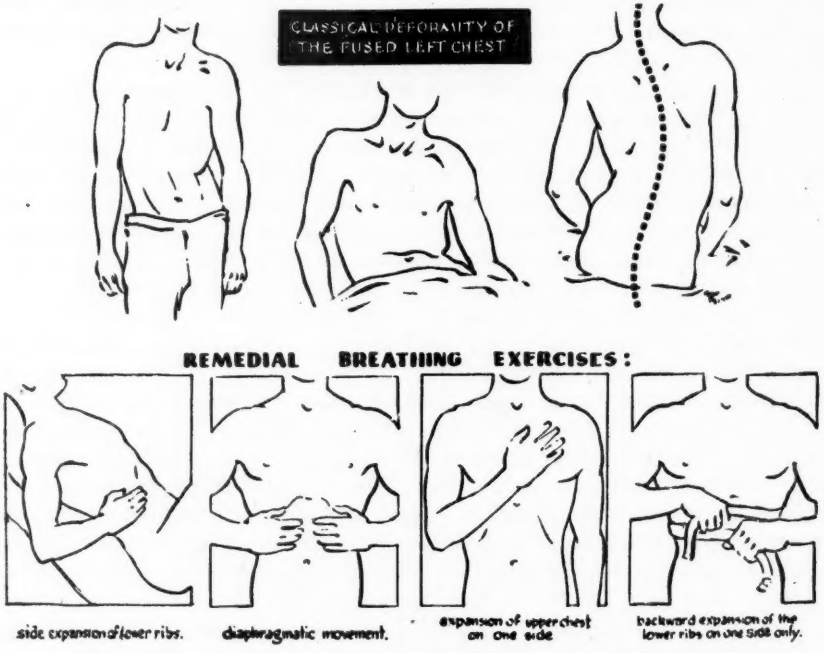
CLASSICAL DEFORMITY OF THE FUSED LEFT CHEST
REMEDIAL BREATHING EXERCISES:
side expansion of lower ribs.
diaphragmatic movement.
expansion of upper chest on one side
backward expansion of the lower ribs on one side only.

Fig. 9.—Deformity of a fused left chest and remedial breathing exercises.

this "finding" or becoming aware of the involved or immobile chest is the important feature. By placing the hand over the affected area, instituting gentle pressure, and exaggerating any existing respiratory excursions or substituting such cycles if they are absent, the patient gradually becomes conscious of a specific area in the chest. This requires concentration on the part of the patient. The manner in which the instructor or the patient delivers the pressure is likewise important; it should be firmer on expiration so that that phase of respiration is exaggerated. On deepest expiration a gentle extra thrust, sharply released, will give the chest wall a spring or recoil that initiates the inspiratory phase. It is often this recoil that the patient picks up and continues in his conscious effort at moving the lagging area of thoracic wall. *During the inspiratory effort the pressure from the hand is just firm enough to establish an afferent*

pathway whereby the patient can become conscious of the area. During the expiratory phase the pressure is much firmer and represents an exaggerated substitute for the normal.

The restoration of diaphragmatic mobility is more difficult than that of the chest wall for three reasons: first, it is impossible for the patient to see his results; second, the costophrenic adhesions or more properly the parietophrenic adhesions are often very dense and are slow to yield to the diaphragmatic pull; third, the patient sometimes has great difficulty in getting the idea of abdominal breathing and more frequently than not will move the abdominal wall precisely opposite to the proper pattern. The key to all three of these problems associated with diaphragmatic mobilization is to explain to the patient that on inspiration the chest wall increases the volume of the thoracic cavity, and therefore the lungs by opening like bellows, and that the floor of the thoracic cavity or diaphragm similarly increases the thoracic volume by dropping downward like a piston. This piston idea seems to be an acceptable description to patients and they quickly realize that their abdominal muscles must relax and be forced out by the descending piston, conversely, that they can force the piston upward into the thoracic cavity by contracting the abdominal muscles and pushing in the abdomen. Progress in diaphragmatic breathing can be best assessed by fluoroscopic examination at five-day intervals.

Lest the foregoing remedial breathing exercises be confused with some sort of calesthenics and dismissed too lightly, it has been elected to omit the discussion of certain additional postural exercises that are, in fact, valuable. However, any comprehensive consideration of the problem will reveal that the exercises involved are: anteroposterior and lateral neck and back bending exercises, arm raising, scapulohumeral and scapular loosening movements. In this thoracic clinic these exercises are done in classes.

The patient will take a more active interest in these exercises and progress much more rapidly if a large mirror is available. He then fully appreciates his problem and progress. Even though his deformity may be described to him in detail the patient cannot believe that he is "out of shape" until he sees it.

The widespread adoption of remedial breathing exercises in this theater attests both the receptive spirit of American medical officers and the conspicuous value of this new therapeutic measure.

MILITARY THORACIC SURGERY IN THE FORWARD AREA

LIEUTENANT COLONEL REEVE H. BETTS AND CAPTAIN WILLIAM M. LEES,
MEDICAL CORPS, ARMY OF THE UNITED STATES

THIS report is based on the experience of a thoracic surgical team of an auxiliary surgical group during the six months' period from December, 1943, to June, 1944. During the first month of this period we functioned in a forward evacuation hospital. From January to June, 1944, the team functioned with a field hospital on the Anzio Beachhead, Italy. During this latter period it was necessary, because of various circumstances, that we work as a general surgical team instead of devoting all of our time to thoracic cases. It was likewise necessary that the general surgical teams with which we were working handle thoracic cases also. Hence, our report in no way should be taken as an indication of the frequency of chest wounds. As we did thoracic operations in preference to others when there was the choice, our report is not a true indication of the proportion of chest lesions to other wounds. During this six months' period a total of 192 patients were treated by our team. Of this number 164 had thoracic injuries. Seven of the 192 died during operation or postoperatively, a gross mortality of 3.6 per cent.

It has not been possible to follow adequately many of the cases through the chain of evacuation. All figures are, therefore, based on the patient's condition at the time of discharge from the hospital where he was operated upon. For the severely injured, this was one to three weeks postoperatively.

Any discussion of battle casualties must take cognizance of accompanying lesions other than the primary one. Oftentimes they in themselves are severe and life-endangering. In this group of thoracic injuries, practically all possible associated lesions were present, including fractured femurs and humeri, traumatic amputations, and two with transection of the spinal cord in the thoracic region. In many, the chest injury was the minor part. No attempt is made to discuss other than the thoracic aspect of the cases.

In an article by Forsee[1] will be found a description of the personnel of a thoracic surgical team as well as a discussion of the various types of medical installations in which they work. Therefore, the facilities of the hospitals will not be set down here.

PREOPERATIVE PREPARATION

Much has already been written on the problem of preoperative preparation of war casualties. Only those phases that are of particular importance in thoracic injuries will be discussed.

The preoperative condition of the thoracic casualty is dependent on many factors such as blood loss, tissue trauma, exposure, and condition of the soldier before injury. In this respect he does not differ from any other battle casualty. The important difference is that he has the all-important addition of a disturbed

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cardiorespiratory physiology. This factor is apt to be by far the most important. All attempts at resuscitation will prove futile unless it is accompanied by correction of cardiorespiratory disturbances. The first step in this procedure is to provide as nearly as possible, an airtight, functional thoracic cage. This means occlusion of sucking wounds and stabilization of the chest wall by any suitable means. Any penetrating or perforating wound of the chest should be considered a sucking wound whether or not any exchange of air with respiration is audible. Wounds that do not suck with the patient in a given position will often be found to suck with motion of the arm or change in position of some other muscle group. Therefore, any wound that enters the thorax should be treated by a firm, occlusive type of dressing after dusting of the wound with sulfanilamide. Large chest wall defects can be closed in a temporarily satisfactory manner for transportation to a field hospital by a sufficiently voluminous, occlusive dressing. If available, sterile petrolatum gauze is preferable for the first layer, both to permit easy removal of the dressing and to provide a more nearly airtight closure. Medical officers in the battalion aid stations, collecting companies, and clearing companies are duly aware of these conditions and such first-aid procedures have usually been carried out before admittance of the patient to the field hospital. Dressings may become deranged during transportation and all patients are therefore checked on this point as soon as they are admitted.

The typical clinical picture of shock can be due entirely to anoxia, the result of disturbed cardiorespiratory function. This has been previously described under the term of "pulmonary shock."[2] It is of prime importance that attention be directed to correction of these abnormalities instead of placing undue reliance on replacement therapy with blood or plasma. Often replacement therapy and restoration of normal physiology proceed simultaneously.

The most frequent cause of anoxia in thoracic injuries is the presence of blood and/or air in the pleural cavity. This reduces the functioning pulmonary tissue to a degree insufficient to maintain adequate oxygenation of the blood. It must be realized that amounts of blood or air that would be of little consequence in the normal individual may be of great importance to the battle casualty when added to the burden already present due to marked blood loss, tissue trauma, and concomitant wounds. Therefore, any appreciable amount of blood or air (that can be defined as any that can be detected on physical examination) is best removed with the least practical delay. Sterile aspirating sets are an important part of the equipment of the shock tent. Aspirations are to be repeated, not according to any time schedule, but as frequently as symptoms warrant it. It is not necessary to move the patient or have him sit up to carry out a thoracentesis. The axillary region is a satisfactory site for removal of fluid and the anterior chest for air.

Excessive pulmonary secretions, as evidenced by a rattling type of respiration or frequent ineffective coughing, interfere with adequate blood oxygenation by impairment of the absorptive function of the alveoli. Such secretions can be removed either by having the patient cough effectively, or mechanically by aspiration of the trachea and bronchi with a catheter. Patients do not realize

the importance of coughing up this material and, if they are sufficiently alert to understand, it should be explained to them in detail. The personnel in the shock tent is instructed to help the patients by holding their chests or supporting the abdomen if coughing causes pain or discomfort in either location. In the conscious patient, pain is the chief deterent to coughing. It is best not to use morphine for its relief. Prompt, prolonged effect will follow blocking of the painful intercostal nerves with 1 per cent procaine. The result is often dramatic.

For those patients who cannot be made to clear their trachea and bronchi by the means enumerated, mechanical aid must be given. Haight,[3] in 1938, demonstrated a simple method for introduction of a catheter into the trachea and major bronchi. With a little practice it is an easy procedure and has been found to be extremely useful. Not only does it remove much of the secretion directly, but the irritation of the catheter will stimulate all but the moribund patients to cough and thus rid themselves of much more than could be obtained by aspiration alone. Usually only one or two aspirations are necessary, but they should be repeated as often as indicated. In a few instances where repeated aspirations were indicated, we have introduced a Magill intratracheal tube which was left in place and the trachea aspirated through it with a catheter at frequent intervals. A more extensive discussion of this problem of traumatic "wet lung" will be found in other papers.[4, 5]

A field hospital admits only first priority cases. This means that a very high proportion of patients are in severe shock at the time of admission, many having blood pressures that are unobtainable. Replacement therapy is a life-saving procedure. It is likewise indicated in thoracic injuries, with due regard being paid to correction of the mechanical disruption of normal oxygenation of the blood. The amount of blood and/or plasma that is necessary and the speed with which it should be given is not germane to this discussion. However, a word of warning is indicated. There is the distinct danger of overloading the already impaired circulation in thoracic cases by too rapid or too vigorous administration of fluids. For hemorrhage nothing is as good as blood, but as blood is not available until the patient reaches the field hospital, we have felt that occasionally too much plasma is given in the aid and clearing stations. This places an extra load on the circulatory system which may decompensate and contribute to the development of the "wet lung" syndrome.

Much attention has been given in World War II to blast injuries to various organs. The lungs are very susceptible. Not only may it be due to the air waves themselves from being near an exploding bomb or high explosive shell but more frequently from the impact of a high velocity missile striking the chest wall. Those missiles that penetrate or perforate the thorax are not as frequently at fault as the ones that strike the chest tangentially or in their course destroy and thus set in motion portions of rib. Moist respirations, blood-tinged sputum, and cyanosis are the more prominent symptoms.

Patients with blast injury and marked shock, in whom one hesitates to give large amounts of blood, will sometimes respond to serum albumin. By its

use the osmotic pressure of the blood is raised with a minimum amount of fluid replacement. In some instances we have found that 25 or 50 Gm. of albumin have elevated the blood pressure and reduced the amount of pulmonary secretion to the point where blood could be given with less trepidation.

The efficacy of oxygen in the treatment of shock in general is still debatable. It would seem, however, that there can be no disagreement as to its indication in all thoracic injuries that show any degree of respiratory difficulty and it has been our practice to use it freely and almost routinely. Anoxia is the greatest lethal agent in thoracic war injuries.

Patients with wounds of the abdomen or extremities should be operated upon as soon as their general condition permits in order to reduce the incidence of infection. Thoracic patients, on the other hand, rarely die of infection; mechanical difficulties are more frequently the cause. It is, therefore, not as necessary to operate upon these patients at the first opportunity. It is our clinical impression that the patient with a severe wound of the chest will do best both during and after the operation if the preoperative preparation is not hurried and he is given a period of time to stabilize after his blood pressure, pulse, etc. have been restored to normal levels. He will withstand operation much better if he has been stabilized for one to three hours than if he is operated upon as soon as the blood pressure has returned to a normal range. Whenever conditions permit we believe it is advisable to postpone surgery for two to three hours.

The last procedure before operating upon the patient is to do a thorough roentgenographic study. Each platoon of a field hospital has complete facilities. We have found that roentgenograms of the chest in at least two projections are always indicated and frequently oblique views or fluoroscopic examination will be desired after the initial study. It is true that in many instances one can determine clinically the approximate damage and the procedures necessary for their correction. It is better, however, to take seemingly unnecessary roentgenograms than to wish for more in the middle of the operation. We have been impressed by the observation that the pathology found at operation is often much greater than was anticipated from the roentgenographic examination. The x-ray has been particularly helpful in separating the thoracoabdominal injuries from those that are limited to the chest. Abdominal pain and rigidity so frequently accompany lesions of the chest that such signs cannot be relied upon to determine the presence or absence of intra-abdominal pathology. Likewise, absent peristalsis is the rule in injuries of the intestinal tract but may still be present with blood in the peritoneal cavity from an injury to the spleen or liver.

ANESTHESIA

The importance of a well-qualified anesthetist for intrathoracic operations has been repeatedly stressed but is of such great importance that it will bear reiteration here. He should be able to relieve the surgeon of all anesthetic responsibility, control shock therapy during the operation, and be able to cope with the ever-present problem of pulmonary secretions and intratracheal blood

by repeated aspiration during operation and by bronchoscopy immediately postoperatively.

As one can never be certain beforehand what procedures will be indicated during the operation it has become our routine to use intratracheal anesthesia for all penetrating or perforating lesions of the chest. With a well-trained anesthetist the induction period is not prolonged more than five to ten minutes and the time is well spent.

Preoperative medication, usually atropine, gr. $\frac{1}{150}$, is given intravenously as soon as the patient is placed on the table. Morphine is not often necessary as in spite of repeated warnings the tendency is still to give patients with chest injuries too much morphine in the aid and clearing stations. Pain is much better relieved by intercostal nerve block. Often at such times the patients are in rather deep shock and the morphine is not picked up by the lagging circulation, which results in the dose being repeated after a short interval. Morphine syrettes are used which contain ½ gr., therefore, that is the dose in most cases. When the patient is brought out of shock the circulation improves and the morphine is picked up, giving a cumulative effect which in an occasional case results in morphine poisoning. For these reasons we have not given morphine routinely preoperatively. If the anesthetist deems it advisable at any time after induction it is given intravenously which is a more satisfactory method of administration.

In lesions involving only the chest wall, local anesthesia is quite satisfactory. Patients on whom a block has been done preoperatively for the relief of pain from fractured ribs, etc., can be operated upon with the additional use of procaine locally. Few battle casualties have only one wound. Most have at least one wound that needs a general anesthetic and hence we have performed relatively few operations under local anesthesia. A detailed account of anesthesia in the treatment of thoracic battle casualties will be found in the report of Bowers.[6] The anesthetist is a very important member of any thoracic team. Not only does he conduct the anesthesia, but by performing paravertebral blocks, intratracheal aspirations, and bronchoscopies he is of great help to the surgeon in the pre- and postoperative care.

SURGICAL TREATMENT

Lesions of the Chest Wall.—In our series of cases there were eighty-two patients who had injuries of the thoracic cage but no penetration of the pleura. There was one fatal case. Soft tissue lesions in this area do not differ from those in other parts of the body and are treated by wound débridement or excision, sulfanilamide powder and petrolatum gauze dressings. In those instances where ribs have been fractured, the nerve accompanying the rib is crushed and a paravertebral intercostal block carried out to provide relief of pain.

The most troublesome lesions of the chest wall that we have had to treat have been the extensive lesions of the shoulder girdle and scapula. A missile of high velocity striking the scapula a glancing blow will often produce very extensive damage to the heavy muscles in the vicinity. The scapula is easily

shattered and becomes badly fragmented. Although wide excision of the damaged muscles must be done, we have left as much as possible of the remnants of the scapula. The upper third of the scapula is by far the most important from a functional standpoint and we have no hesitancy in removing as much as necessary of the lower two-thirds in order to do an adequate débridement. The danger of gas infection in this heavy muscle group is considerable. The one death that occurred was due to *Clostridium oedematiens* although we had done what we thought was a very radical débridement. Because of this threat we have on occasion had to make a large paravertebral incision in order to treat adequately a subscapular wound, even though it did not produce any intrapleural damage.

Penetrating or Perforating Wounds of the Chest.—Collectively, penetrating or perforating wounds are usually referred to as "sucking wounds" of the chest. In some respects, the term is unsuitable and meaningless. It has become so widely accepted, however, that some explanation must be offered for not discussing it as such. Any penetrating or perforating wound of the chest may suck if the tissues overlying the pleural defect are so aligned as to present an opening. A small wound anteriorly where there are few muscles may suck, whereas a large wound through the heavy muscles of the back may not suck. What is more important is that a wound that may not suck with the patient in one position may suck very markedly with a change in position. Therefore, it is ill advised to instruct all medical personnel to occlude adequately only sucking wounds. Emphasis should be placed on so treating any wound that may have penetrated or perforated the pleura. Patients are most frequently transported lying supine on a stretcher, but very few soldiers are injured while they are lying in that position. The shift of muscle groups with the change of position prevents many of the wounds from sucking. A good general rule is to keep the patient lying on the injury, and to put an occlusive dressing on any chest wound.

As a certain amount of blood is always present in the pleural cavity in any penetrating or perforating wound, hemothorax is a major consideration. Untreated hemothoraces have presented a problem to those working in the rear echelon.[7] Frequently they have had to do decortications to remove the layer that forms over the pleura and prevents lung expansion. It is, therefore, of importance that all hemothoraces be evacuated as completely as possible. We believe that this should start as soon as the patient is admitted to the field hospital. As previously stated, any gross amount of fluid in the chest should be aspirated, not only to remove the blood, but to improve the respiratory function. The amount of blood obtainable gives some indication of the severity of the damage and aids in appraising the structures that may be injured and deciding the best means for their repair. It seems advisable to not remove over 1,200 to 1,500 c.c. of blood at any one time but the aspiration may be repeated in one hour or so if indicated. The amount obtained by aspiration is a good guide to the amount needed to be given by transfusion.

Aspiration of blood followed by air replacement is mentioned only to be condemned. About the only conceivable indication for air replacement is to

control bleeding from the pulmonary parenchyma. Bleeding from the lung itself has never been observed by us to be severe. If the source of the bleeding is a large hilar vessel or one of the systemic circulation vessels, it seems wholly unwarranted to expect the slight increase in intrapleural pressure to be at all effective in its control. It is much more difficult to remove air from the pleural space than it is fluid. Consequently, when air replacement is practiced, re-expansion of the lung is more difficult to obtain. Furthermore, a hemothorax is a good culture media for bacteria and hence one of the dangers of hemothorax is the production of an empyema. If an empyema occurs in a hemothorax ten to fourteen days after onset, the lung will in most cases already be adherent to the parietal pleura except over the collection of fluid. Thus, the empyema is localized. If air replacement has been used and infection sets in, a total empyema is unavoidable.

In patients who do not have a thoraco-abdominal lesion, we have made it a practice to use the blood aspirated from the chest as an autotransfusion. The possibility of contamination from the stomach or colon contraindicates such a practice if these organs may have been injured by a missile traversing the diaphragm. Blood in the pleural space sometimes clots and sometimes does not. Although we believe all blood should be removed, we do not feel that it is an indication for a thoracotomy done in the forward area. It is certain that adequate evacuation of a hemothorax in the forward area will obviate the necessity of a later decortication to prevent formation of a fibrothorax and impairment of the pulmonary ventilation. Every effort should be made, therefore, to remove all blood possible as soon as practical.

We have arbitrarily divided the penetrating and perforating wounds of the thorax into two groups, the large and the small, as the surgical treatment of them differs. The smaller ones are referred to simply as penetrating or perforating wounds. The large ones, by which we mean any that produce a pleural defect of 6 cm. or more or which destroys three or more ribs and all intervening structures, are called large chest wall defects or traumatic thoracotomies. The latter term is employed because when the wound is débrided one is presented with a pleural defect of such extent that any necessary intrathoracic procedures may be carried out. The operation, therefore, becomes a thoracotomy.

The surgical treatment of the first group, the small penetrating or perforating lesions, resolves itself into treatment of the wound, removal of blood and/or air from the pleural space, re-expansion of the lung, and the securing of an air-tight closure. This group (pleural defect less than 6 cm.) does not present any great difficulty in chest wall closure. Very frequently it is not possible to close the pleura itself, but we feel it is of little importance and make no attempt to do so unless it is easily done. This means, however, that there is an opening between the chest wall structures and the pleural cavity. Thus, any infection occurring in the soft tissues of the chest wall can easily extend into the pleura producing an empyema. For that reason we advocate a very radical débridement of the missile tract. In fact, wound excision would be a more appropriate name for our method of treatment. In this group of smaller lesions, closure does

not present any problem and therefore one should feel free to excise as widely as necessary.

All but the most minor wounds will leave a pleural defect sufficient to admit a 16 or 18 French catheter. In any patient who has a detectable amount of blood in the pleura, we insert a catheter through the pleural opening and aspirate all that is obtainable by attaching the catheter to a suction machine. A hole is made in the catheter near its proximal end in order that the amount of suction applied is controllable with the finger. We are especially anxious to carry out this procedure in those that have clotted blood that cannot be obtained on thoracentesis. It is often necessary to work the catheter back and forth to break up the clots. After as much as possible is obtained, the pleural space is washed out with 1,000 to 2,000 c.c. of normal saline solution and this likewise aspirated through the catheter. Preliminary sutures are placed in the muscles around the catheter after dusting with sulfanilamide and the sutures are tied down as the catheter is withdrawn. Just before removing the catheter, the anesthetist increases the intrabronchial pressure to plus 12 cm. or 15 cm. of water in order to re-expand the lung. The positive pressure by the anesthetist and the negative pressure created by the suction on the catheter results in good expansion of the lung. When the muscle sutures are tied, the chest then becomes airtight. We use this same method of closure following a thoracotomy. It has been our practice not to close the skin after débriding the smaller wounds. A petroleum jelly dressing is applied. Pleural cavities that are treated in this manner and in which the blood has been adequately evacuated will not often form enough fluid to warrant any further aspirations. If it should so develop, or for some reason subsequent examination reveals any air remaining, it is aspirated and such aspirations repeated until the lung is fully expanded and the pleural space is dry.

Rarely a tangential blow to the chest will result in the fracture of one or more ribs in such a manner that the sharp rib ends penetrate the pleura even though the missile does not. No doubt most of these will cause no difficulty, but it is possible to so produce a pneumothorax and in some instances, by continued trauma to the lung, to invite infection. This can result in an empyema or a lung abscess. Although we have not had any such complications personally, we have seen one patient in whom a lung abscess and empyema were undoubtedly caused in this manner. The abscess was treated in the usual manner[8] and a good result was obtained. It would, therefore, seem advisable to inspect carefully all fractured ribs. If it is determined that some of the fragments have penetrated the pleura they should be resected.

In the period covered by this report we have observed and treated forty-nine patients with penetrating or perforating injuries of the chest, in whom the pleural defect was less than 6 cm. in diameter. There were no deaths in this group.

THORACOTOMY

Of the sixty-three patients in this series with penetrating or perforating wounds of the chest (exclusive of the nineteen thoracoabdominal lesions),

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SCHOOL OF MEDICINE

thoracotomy was done on twenty-eight. There were two operative deaths, a mortality of 7.1 per cent.

Indications for Thoracotomy to Be Done in the Forward Area.—As far as we are aware, there has not been set down by anyone with experience, the indications for thoracotomy in the forward area. We firmly believe that major, intrapleural procedures should be curtailed to a minimum in the more advanced medical installations. However, there are certain patients that must be operated upon there because of the nature of the injury or because the increase in injury to operation time would seriously jeopardize chances of recovery. Local conditions will vary the indications. Such things as the ease of evacuation, condition of the roads, and facilities of the hospitals in the rear must all be considered. Likewise, the indication for thoracotomy in an evacuation hospital is frequently different than that in the field hospital.

We have been able to classify our thoracotomies into three main groups: (1) traumatic thoracotomies, that is, large chest wall defects in which simple débridement of the wound produces a pleural defect of sufficient size to permit the necessary intrapleural manipulation (pleural defects 6 cm. or greater); (2) thoracoabdominal injuries; (3) miscellaneous factors that must, on occasion, be considered indications for thoracotomy, namely, uncontrolled hemorrhage, large lung lacerations, and foreign bodies.

Traumatic Thoracotomy.—The one main indication for thoracotomy (excluding thoracoabdominal injuries) is the large chest wall defect. As defined previously, this indicates a pleural defect of 6 cm. or more in diameter, or destruction of three or more ribs and all intervening structures. We have had fourteen such cases. Two deaths occurred, one of which will be reported in detail.

In our series of traumatic thoracotomies the causative agent was most frequently a fragment of high explosive shell. In a few instances a bullet striking the thoracic cage tangentially or emerging from the chest in an erratic course produced a disproportionately large chest wall defect. The size of the foreign body was not proportional to the size of the defect. The velocity of the missile seemed to be of more importance. In one instance two bullets from an automatic weapon struck the chest in close proximity producing thereby a greater defect than the sum of the two injuries would have been had they been farther separated.

A traumatic thoracotomy is performed through the wound of exit if it is a perforating wound or through the defect if a tangential wound. As it is desirable, and in many of the large chest wall defects imperative, that the wounds be closed tightly we have felt that they should be débrided even more radically than those that are left open. That this plan is effective in diminishing the incidence of infection is evident from the lack of infection noted in these patients. Up to the time of their evacuation, ten to twenty-one days postoperative, we did not see one wound infection or even a stitch abscess. We realize that the group was very small but it indicates the effectiveness of radical treatment of the wound.

As much of the ribs and intercostal structures as possible should be preserved to prevent paradoxical motion of the chest postoperatively. We, therefore, only remove the loose fragments of bone and tissues that are devitalized. Rib fractures that have not penetrated the pleura are left strictly alone. The rough, sharp edges of rib stumps are smoothed up with the rib cutter. The inner or outer table alone of the fractured rib may be displaced. In such cases the remaining half is left in place as a half rib gives more support than no rib. All damaged intercostal bundles are ligated anteriorly and posteriorly even though observed not to be bleeding at the time. When easily accessible the nerve is crushed but not included in the suture ligature. To prevent postoperative pain and to encourage full respiratory excursion the nerve accompanying the rib above the lesion is crushed. In most instances we have done a paravertebral nerve block with 1 per cent procaine of all nerves on the injured side that were not visualized and crushed at operation.

Intrapulmonary bone fragments will be found in practically all of these traumatic thoracotomies. They are removed, all lung lacerations repaired (to be discussed), blood is removed from the pleural space which is then washed out with one or two liters of normal saline solution, and the chest closed after deposition of 5 or 10 Gm. of sulfanilamide in the pleural cavity. Great care is taken to secure complete lung re-expansion by use of positive pressure plus intrapleural catheter aspiration.

Some ingenuity is often necessary to effect an adequate closure of the chest wall. No attempt is made to close the pleura or intercostal structures. In some instances we have used catgut pericostal sutures to approximate separated ribs and reduce the size of the costal opening. Posteriorly adequate muscle can be mobilized to cover the pleural defect. Low on the thoracic cage near the spine, muscles are not so plentiful and we have frequently had to swing a flap of the paraspinalis muscles to close the defect. Anteriorly the pectoral muscles are all that are available. If possible these are used, if not, one has to rely on the subcutaneous fascia and skin. It has been suggested that the diaphragm be used to close certain strategically placed defects in the lower thoracic cage. We have not had to resort to this procedure but have on occasion paralyzed the diaphragm to help diminish the size of the hemithorax and to lessen the strain on the wound during the immediate postoperative period. Certain posterior chest wall defects can be adequately covered by fixing the arm in a position that places the scapula over the desired area.

The dressing is of great importance in traumatic thoracotomies. Care is taken to give maximum support to the thoracic cage by a liberal use of wide adhesive passing to or beyond the midline both anteriorly and posteriorly. The skin is first painted with tincture of benzoin or A.C.E. adherent to secure good traction and to prevent skin blisters that often form when adhesive is applied tightly without this precaution. Such a supportive dressing minimizes the paradoxical motion of the chest, keeps the muscles and thoracic cage in approximation, and by restricting motion, and therefore pain, aids the patient in expectorating material from the tracheobronchial tree.

Thoracoabdominal Injuries

The term thoracoabdominal implies that the same missile entered both the pleural and abdominal cavities and thus traversed the diaphragm. For those patients in whom separate missiles have entered the two cavities the term thoracic and abdominal injury is preferable. In our series all cases belong to the first-named group.

As a group, these patients are the most severely wounded and have the highest mortality rate of all patients admitted to the field hospitals. Michels[9] reported on ninety-seven such cases and found a mortality rate of 43 per cent. Our series is small, being composed of only nineteen cases. Of this group, seventeen patients were operated upon. One died preoperatively, and one other, a prisoner of war, was not operated upon by us because it was necessary to transfer him to another installation. Of the seventeen operated upon, three died, a mortality rate of 17.6 per cent. The fatal cases will be discussed in detail.

Various combinations of organs were injured. The following denotes the number of times each organ was involved: liver 11, spleen 6, stomach 5, colon 3, small intestine 2, pancreas 1, kidney 1, adrenal 1.

Approach.—Thoracic surgeons are thoracically minded, general surgeons are abdominally minded. Thus, they tend to approach thoracoabdominal injuries differently. This is as it should be. There are certain injuries which all agree are best repaired through the chest and diaphragm. There are others, fewer in number, in which obviously there has been little intrapleural damage, and in face of considerable abdominal injury, are best repaired from below. There is no argument but that lesions of the diaphragm, spleen, liver, upper portion of the stomach, transverse colon, splenic flexure of the colon, upper one-half of the small intestine, and kidneys can be handled as well or in some instances with much greater facility from above than from below. Extensive damage to the diaphragm or pulmonary trauma cannot be as adequately repaired from below as from above. Lesions of organs in the abdomen, other than those just mentioned, may not be amenable to treatment from above. In view of the necessity of an adequate diaphragmatic repair and restoration of normal cardiorespiratory physiology, we believe the tendency should be to do all questionable cases transthoracically even though exploration at that time may reveal pathology in some cases that cannot be treated in an acceptable manner from above. In such instances, a separate abdominal incision should be made. Extension of the thoracic incision over the costal margin onto the abdomen has been advocated by some but has not been used by us. We prefer to make a separate incision when the exposure through the diaphragm proves inadequate. Many surgeons feel that because of the risk of infection, all colon injuries should be repaired from below. In the three cases in which we found perforations of the colon and an exteriorization was done from above, infection did not develop.

Thoracotomies have usually been done through an extension of the original wound. This has not been true of the thoracoabdominal cases. A thorough exploration of the chest and abdomen can be accomplished with ease only if the incision is placed between the eighth to tenth ribs. Space is too limited below

the tenth rib for adequate exposure. If the wound does not fall in this designated area, we make it a practice to enter the chest through a separate incision.

Thoracoabdominal injuries low on the right side posteriorly may be approached extrapleurally by resecting either the twelfth or eleventh rib and dissecting up the lip of the pleura, repairing the defect in it, and approaching the liver either through the hole in the diaphragm made by the missile or through the bed of the resected twelfth rib as used for drainage of a subphrenic abscess. We have had opportunity to do this on only one occasion when it was quite certain that the liver was the only abdominal organ involved and likewise there was no evidence of severe pulmonary damage. The liver was thus packed and drained very easily and safely.

Diaphragmatic Repair.—For repair of the diaphragm we have used a two-layer, interrupted, imbricating type of suture. Cotton or silk has been used in all cases. Although diaphragmatic hernia is not so great a threat on the right side as on the left, Jarvis[10] found that there is an appreciable incidence of bile empyemas following right-sided thoracoabdominal injuries. We believe that any sizable lesion of the liver should be drained and the drain brought out subcostally through a stab incision. We are convinced that this will reduce the incidence of subphrenic collections as well as bile empyemas.

Hemorrhage, Bone Fragments, and Lung Lacerations

Intrapleural hemorrhage must be either from the pulmonary or from the systemic circulation. Bleeding from the pulmonary parenchyma is not often life endangering, whereas bleeding from one of the vessels in the pulmonary hilum may cause rapid exanguination. It has been our experience that the latter are so quickly fatal that the patients do not reach even the field hospital. In this series of cases there were no lesions of the large hilar vessels.

Severe bleeding most often arises from one of the systemic vessels. The intercostals, internal mammaries, or pericardiophrenics may be the source. It has been surprising to us to note at operation how frequently severed intercostals had ceased to bleed and how infrequently any bleeding could be found at operation even through 1,000 to 2,000 c.c. of blood may have been aspirated preoperatively. We do not intend to infer that uncontrolled hemorrhage is not an indication for thoracotomy or that a patient may not die from a severed intercostal vessel, but we have not seen it. We have found the pericardiophrenic vessels divided at operation but they were not bleeding at the time. The internal mammary is potentially the most dangerous but our experience with injury to this vessel has been meager. We have not seen it as the source of uncontrollable hemorrhage. It therefore seems likely that division of one or more of these vessels will produce a marked intrapleural hemorrhage but the reduction in blood pressure caused thereby will allow the vessel to clot and seal off. The only vessels we have observed to be actually bleeding at the time of thoracotomy have been those intercostals that were incompletely divided and hence unable to retract.

In a discussion of uncontrollable hemorrhage, mention must be made of lesions of the heart. We have not personally treated any perforating or penetrating lesions of this organ but have seen one and know of another. One patient was operated upon and died while on the table; the other was not operated upon but was treated by repeated aspirations; he also died, on the third day. There are undoubtedly a few cases in which the missile has lodged in the myocardium that should be removed but we have had no experience with that type of case. The only heart lesion that we saw was one with a small gutter type wound that did not cause any severe bleeding. There must also be an occasional injury that produces cardiac tamponade which will require surgical relief.

Intrathoracic foreign bodies do not very much concern the thoracic surgeon in the forward area. It has been shown that very few cause any difficulty later on and it has been our policy to leave them alone except for one or two instances where a thoracotomy was done for some other indication and the foreign bodies were removed because they were easily accessible.

It has been our observation that bone fragments from fractured ribs that have been set in motion by the impact of a missile are apt to produce far more lung damage, because of their irregular, jagged surfaces, than the foreign body itself. They often produce long, ragged lacerations of pulmonary tissue. When, after finishing the débridement down to the pleura, one is able to observe the lung through the defect and can see multiple bone fragments in the lung or extensive lacerations of the pulmonary parenchyma, we believe that it is a good practice to extend the pleural incision and repair the damage. We are especially concerned with those patients who have fragments of bone partially within the parenchyma and partly in the pleural space. It seems likely that such foreign bodies will produce considerable lung trauma as the lung re-expands and the fragments come in contact with the chest wall. It may result in any air leak or provide an avenue for infection. All holes in the lung are tested for air leaks by filling the chest with saline solution and inflating the lung with 10 to 15 cm. of water-positive pressure.

The recuperative power of a lobe is immense. We believe this is due to the blood supply which, being in the form of a tree, can be irreparably damaged only by severing the trunk. Casualties that suffer such misfortune (injury to the hilar blood vessels) do not reach even the most forward hospital. We have not done a resection on even the most severely damaged lobes. At first we sutured these extensive lacerations with trepidation, fearing that the lobe might slough but have been happily surprised to see the comparatively rapid clearing of the process on serial postoperative x-ray pictures. We have had little success with a deep layer of sutures in repairing lung lacerations. The friable, hemorrhagic pulmonary tissue will not withstand even gentle tension. Therefore, we now do a simple, one-layer, interrupted closure with nonabsorbable sutures on an atraumatic needle. It is surprisingly easy to secure an airtight closure because the hemorrhagic lobe does not aerate well at first and the tendency to leak is thereby diminished.

Injuries to the Mediastinum.—Lesions of the heart, pericardium, and great vessels have already been mentioned. We have not had any case in which there

was damage to the intrathoracic trachea or esophagus. Although we have had three patients in whom moderate-sized missiles crossed the mediastinum, they did so in such a manner as to be innocuous. Should we be faced with a lesion of the thoracic esophagus we would attempt to approach it posteriorly through an extrapleural exposure, hoping to seal off the lesion from the pleural cavity. A primary repair would be attempted and the posterior mediastinum drained.

Pleural Drainage.—The question of drainage of the pleural space following either a thoracotomy or a thoracolaparotomy is a personal problem best handled by the surgeon as he sees fit. The lung must be expanded and brought in apposition with the chest wall as quickly as possible. This can be done by underwater drainage through a catheter or the same end can be achieved by thoracentesis as often as indicated. Personally, we favor the latter method and have been pleased to note the number of patients who do not need aspiration at all when care has been taken to get good expansion of the lung before closure of the thoracic cage. If drainage is not employed, thoracentesis must be performed when there is any evidence of remaining fluid or air. A good rule is to aspirate daily as long as 100 c.c. or more of either fluid or air is obtainable. When less than that amount, aspiration every other day is sufficient until the pleural space is dry and the lung completely expanded.

POSTOPERATIVE CARE

Probably more patients with thoracic injuries die because of poor postoperative care than because of poorly executed surgery. Postoperative treatment begins on the operating table. It consists of adequate lung expansion and removal of all intrabronchial material. If these two requisites are fulfilled and maintained in the postoperative ward, convalescence is practically certain to be uneventful. Expansion of the lung has already been discussed. Removal of bronchial secretion deserves further comment. Although the anesthetist has kept the patient dry by tracheal suction all during the operation, he should aspirate again just before and during removal of the intratracheal tube. The patient should be conscious enough by this time to react and will cough from the tracheal stimulation and thus aid the removal of material beyond the reach of the catheter. At best, catheter aspiration is a blind procedure and it is therefore our policy, with a very rare exception, to do bronchoscopy on all patients at the completion of the operation. This is done by the anesthetist and if the position of the patient is such as to make it feasible, the bronchoscopy is performed while the surgeon is finishing the closure of the wound. The anesthetist should so judge the anesthesia that the patient will be sufficiently relaxed to permit easy introduction of the bronchoscope but yet conscious enough to be so stimulated thereby as to make him cough.

One very rare complication that may be encountered when bronchoscopy is being done on a patient in this "in between" stage of anesthesia, is the so-called vagovagal reflex. It was our practice in civilian surgery always to administer atropine, gr. $\frac{1}{100}$ or $\frac{1}{75}$, intravenously just before bronchoscopy because this drug effectively blocks the reflex. For a time we did not do this in treating battle casualties but one such fatal case resulted in a prompt renewal of the practice. A report of the case is appended.

We have attempted to keep the patient's fluid intake from 2,500 to 3,000 c.c. per day. More important is to maintain a urinary output of approximately 1,000 c.c. per twenty-four hours. This is especially important in war surgery where all patients are routinely given sulfadiazine. Care should be taken that patients with pulmonary damage, such as severe hematomas and blast, are given intravenous fluids slowly so as not to overload the lesser circulation. The same indications for blood and/or plasma in the postoperative period obtain as for general surgical patients. Plasma protein and hematocrit determinations will frequently reveal a surprisingly low red cell concentration and blood protein level even in patients who have had large amounts of blood previously.

Pain is not a common complaint in postoperative thoracic patients. When present, it is much better controlled by repeated paravertebral procaine blocks than by morphine. This block can be done without moving the patient from his bed and will last far longer than an injection of morphine. It is imperative that the patient be kept comfortable, otherwise he will not cough and raise the secretion that collects in the bronchi. Every effort should be made by detailed explanation of the problem to the patient and by instructing the ward personnel in its importance and showing them the way to hold the patient's chest so as to make coughing as easy and effectual as possible. Whenever these simpler measures fail, tracheal aspiration with a catheter or bronchoscopic aspiration is indicated. When there is any doubt as to whether or not to do a bronchoscopic aspiration on a patient, the doubt is sufficient evidence that it should be done. Thoracentesis and tracheal aspiration are the two most important measures in the postoperative care of thoracic patients.

Oxygen by BLB mask or nasal catheter should be used freely. All measures in the postoperative treatment are designed primarily to prevent anoxia, the postoperative patient's greatest enemy.

CASE REPORTS

Representative cases are summarized here. One patient with traumatic thoracotomy and one with thoracolaparotomy who recovered are presented. In all the thoracic injuries there were six deaths. One patient with a lesion of the chest wall died of *Cl. oedematiens* infection. Two patients with traumatic thoracotomies died; one case is reported, the other patient died of anoxia from a five-hour preoperative blood pressure of 0/0. Three thoracolaparotomies ended fatally. One will be described. The other two patients died in the third postoperative day, of anuria. This was attributed in one to seven transfusions (3,500 c.c.) of "O" blood (patient was type "A"), the other to a large infarct of the kidney.

CASE 1 (No. 142).—A soldier, aged 34 years, was injured by a bullet at 1:30 A.M., Feb. 21, 1944. He was admitted to the field hospital at 6:15 A.M., having had morphine, gr. ½, at 1:30 A.M. and plasma, 1 unit, at 3 A.M. On admission the patient was conscious but in marked shock. There was complete motor and sensory paralysis below the umbilicus. Bilateral sucking chest wounds were present posteriorly with diminished breath sounds on the left side. X-ray examination showed a compound, comminuted fracture of the right scapula, right ninth and left tenth and eleventh ribs. Both lung fields were cloudy. Pre-

operative treatment consisted of 1,000 c.c. of blood and 1,500 c.c. of plasma. Blood pressure recordings during this period are not available except the single recording of 90 systolic at the time the patient was taken to the operating tent.

At 10 A.M., a thoracotomy was done on the left side with closure of bilateral sucking wounds and laminectomy of the ninth, tenth, and eleventh dorsal vertebrae. Anesthesia used was intratracheal gas-oxygen ether.

On removal of the dressings it was found that the patient had a small wound of entrance at the lower level of the right scapula. The wound of exit was 14 cm. in length over the left tenth and eleventh ribs posteriorly. There was a defect in the left chest wall and pleura that would admit a hand. The wounds were thoroughly débrided. The right ninth rib was fractured and sufficiently removed to permit closure of the small sucking wound. On the left side many bone fragments were removed from the pleura and lower lobe. A 7 cm. laceration of the lower lobe was repaired by interrupted silk sutures. A moderate amount of blood was aspirated and the chest washed out with 1,500 c.c. of saline solution. Because of the location of the injury the left side of the chest could not be closed until after the laminectomy. The ninth, tenth, and eleventh dorsal spinous and transverse processes were completely shattered. When they were removed the cord was fully exposed. It did not pulsate. The dura was intact so not opened. A small needle was inserted and bloody fluid obtained. Five grams of sulfanilamide were deposited in the left pleural space. After introduction of a catheter for underwater drainage the chest wall was closed in layers and the defect in the chest wall protected by suturing the latissimus to the paraspinalis muscles. The wound of entrance was then débrided, including removal of the loose pieces of the fractured scapula. Bronchoscopy was performed and an indwelling catheter was introduced into the bladder.

Postoperative Course.—The patient had a rather stormy time for the first week. The pleural catheter was removed on the third postoperative day since it had stopped draining. It was necessary to aspirate the chest frequently both before and after removal of the tube. He had a large amount of pulmonary secretion, but was always able to raise it effectively when pressure was made on the lower chest and upper abdomen. A plaster jacket was made and the patient evacuated on the tenth postoperative day. At that time he had no return of motor or sensory function below the umbilicus.

CASE 2 (No. 223).—A soldier, aged 35 years, was injured by a bullet, at 2 A.M., April 19, 1944. In Battalion Aid Station he was given morphine, gr. ½, at 4 A.M. At Collecting Company at 5 A.M., he was given morphine, gr. ½, and plasma, 1 unit. At 7:45 A.M., plasma, 3 units, was given; caffeine sodium benzoate; at 9 A.M., plasma, 2 units. On admission to the field hospital at 10:15 A.M., the patient was conscious but in shock, with blood pressure 80/45, pulse 104. Oxygen was started by BLB mask. At 10:40 A.M., a left thoracentesis was done removing 650 c.c. of blood. At 10:50 A.M., 700 c.c. were given by transfusion. At 11 A.M., blood pressure was 78/45; at 11:15 A.M. 100 c.c. (25 Gm.) serum albumin were given. At 12:15 P.M., blood pressure was 100/60, pulse 90. At 12:30 P.M., a blood transfusion of 500 c.c. was given; at 1 P.M., blood pressure was 102/58, pulse 86. At 1:25 P.M., blood pressure was 115/56, pulse 104, and the patient was cyanotic without oxygen. Breath sounds were audible but still diminished on the left side. Coarse râles could be heard on both sides. Examination of wounds showed a 1 cm. wound of entrance just lateral to the first thoracic vertebra, and a 12 cm. wound of exit in the left axilla over the fourth and fifth ribs. X-ray showed moderate left hemopneumothorax with extensive pulmonary haziness. The right lung field was well aerated but markedly increased lung markings extended out from the hilar area. There were compound, comminuted fractures of the left scapula and ribs three, four, five, and six.

At 1:40 P.M., thoracotomy was done under intratracheal gas-oxygen-ether anesthesia. A left parascapular incision was made curving upward to include the wound of entrance. The muscles were divided and a large hematoma was found in the muscle and fascia of the chest wall. The scapula was freed and elevated. It was badly comminuted including the glenoid fossa. Ribs three, four, five, and six were comminuted with flail type chest wall beneath the scapula. The rough rib ends were smoothed up. A piece of fourth rib had lacerated the upper

lobe for a distance of 6 cm. The pleural defect readily permitted exploration of the pleural space, and 700 to 800 c.c. of blood, mostly clotted, were removed. The entire upper lobe was a large, boggy hematoma. There was no gross bleeding. The laceration was repaired with interrupted cotton sutures. The chest was irrigated with 2,000 c.c. of saline solution. Sulfanilamide, 5 Gm., was placed in the pleural space. Routine closure was carried out in layers. Positive pressure, 12 to 15 cm. of water, was administered during the closure and it was at this time that the patient went into collapse. He was immediately turned on his back and the operation stopped. He died at 4:30 P.M., twenty minutes after positive pressure was first applied.

Post-mortem Examination.—The heart was markedly dilated, especially the right ventricle. Grossly the heart and major vessels showed no other abnormality. In one area of the right ventricle just below the auriculoventricular junction there was a firm, white area 1.5 cm. in diameter that resembled an old infarct. The left lung was removed and the entire upper lobe was dark red from hemorrhage and felt like liver. The hematoma extended into the hilum although no gross injury to a major vessel was found. There was a hematoma of the posterolateral aspect of the superior division of the lower lobe. From the cut surfaces of the upper lobe, blood and blood clots exuded leaving small areas of excavation up to 1 cm. in diameter. The lower lobe surfaces on cutting exuded a moderate amount of frothy fluid. The right lung was heavier than normal with diffuse subcrepitant areas. Spread throughout the lobes were small areas of atelectasis or consolidation.

Comment.—The increased load on the heart from the increased intrabronchial pressure together with an old myocardial infarct no doubt contributed to the fatal outcome. It is probable that this patient may have made better progress if he had not been operated upon for another few hours. Although his blood pressure seemed to be quite well stabilized, the lungs showed signs of impending pulmonary edema. The slow response to shock therapy until after the use of serum albumin was an indication of a very poor cardiovascular reserve. We also believe that he had more plasma (6 units) than was warranted. All this fluid intake increased the burden on the already damaged heart.

CASE 3 (No. 176).—A soldier, aged 30 years, was injured by high explosive shell fragments at 5 P.M., March 8, 1944. He was admitted to the field hospital 8:30 P.M., having had 1 unit of plasma prior to admission. He was given 1,000 c.c. of blood preoperatively and 1,000 c.c. during operation.

Examination and Diagnosis.—A penetrating wound was found, 3 cm. in diameter, in the left side of the chest, in the midaxillary line, over the tenth rib; two penetrating wounds, 2 cm. in diameter, were in the left shoulder over the trapezius muscle; two penetrating wounds, 3 mm. in diameter, were in the left side of the neck. There was a perforating wound of the left hip, lateral surface, and a penetrating wound, 3 cm. × 5 cm., over the ramus of the left mandible. The abdomen was rigid and tender. Rebound tenderness was present. X-ray examination showed 25 per cent collapse of the left lung, two large foreign bodies visible over the upper part of the chest, two foreign bodies in the left mandible, and two small foreign bodies in the left side of the neck. There was one large foreign body in the abdomen just to the left of the midline at the second lumbar vertebra.

At 10:15 P.M., thoracolaparotomy and laparotomy were done, and débridement of the multiple wounds. Intratracheal gas-oxygen-ether anesthesia was used. Because of the multiple wounds and the possibility that some of the upper chest missiles may have entered the pleura it was decided to proceed with the treatment of all the minor wounds before the thoracoabdominal.

Wounds of the left shoulder were incised and devitalized tissue was removed. It was necessary to elevate the upper portion of the scapula through a parascapular incision in order to expose the subscapular space. One foreign body was removed from beneath the spine of the scapula and the other from within the rhomboid muscles at the same level. Trapezius

muscle was repaired but skin left open. Wounds of the neck were excised and one small foreign body was removed. Wounds of the left jaw were excised, a foreign body was removed from the mandible, and another from the subcutaneous tissues. The submaxillary gland was found to be lacerated. This was repaired and the skin closed. The two wounds of the left hip were connected and débrided. The tract extended into the subtrochanteric bursa and the greater trochanter was gouged out to a depth of 0.5 cm.

The wound of entrance in the left chest was excised. The tenth rib was found fractured, fragments were removed, and a sucking wound of the chest was found. The foreign body had obviously not done much damage in the chest but had torn through the diaphragm near its attachment. The lung was expanded and no gross pathology found, therefore it was decided to close this incision and explore the abdomen through a separate abdominal incision. This was done and the abdomen opened through a left upper paramedian incision. Exploration revealed three perforations of the upper ileum with the foreign body lying within the lumen. This was removed and the holes repaired in the usual two layer manner. The foreign body had traversed the retroperitoneal space for quite some distance but had not injured the spleen, kidney, or colon. Five grams of sulfanilamide were placed in the abdomen and it was closed in layers. Bronchoscopy was done. The operative procedures consumed a period of three hours and twenty-five minutes. The patient's blood pressure preoperatively was 80/50 and the pulse rate 98. At the end of the operation the blood pressure was 95/65 and the pulse 95 (1,000 c.c. of blood during operation).

Postoperative Course.—This patient had a very uneventful convalescence. We were able to remove the stomach tube on the third day; by the fifth day he was passing flatus. It was never necessary to aspirate the chest postoperatively. The patient was evacuated in good condition on the eighth postoperative day.

May 12, 1944, approximately two months after operation, this patient returned to full military duty. He subsequently led the Signal Company which laid the first wires into Rome on June 5, 1944.

CASE 4 (No. 246).—A soldier, aged 23 years, was injured by high explosive shell fragment, 7:30 A.M., May 26, 1944. Morphine, gr. ½, and plasma, 3 units, were given before admission to the field hospital at 11:30 A.M. On admission, blood pressure was 84/50, pulse 120. One unit of plasma and 1,400 c.c. of blood were given preoperatively.

Examination and Diagnosis.—There was a wound of entrance 4 cm. in diameter over the eleventh rib, in the posterior axillary line, on the left side. The wound of exit, 6 cm. in diameter, was in the anterior axillary line. Omentum had herniated through both wounds. The left chest was silent, the abdomen rigid and tender. X-ray revealed a diffuse haziness throughout the entire left lung field.

At 2:30 P.M., a left thoracolaparotomy was performed under intratracheal gas-oxygen-ether anesthesia. The wounds of entrance and exit were débrided. Incision was made from the wound of exit posteriorly over the ninth rib. A large hematoma of muscles was excised. Segments of ribs eight, nine and ten were found shattered. The rough edges were smoothed up. Intracostal incision was made through the eighth interspace. The pleural cavity was found to contain approximately 1,000 c.c. of blood. Part of the stomach, transverse colon, and spleen covered by omentum had herniated into the left side of the chest through a huge rent in the anterolateral portion of the diaphragm where it attaches to the chest wall. A narrow cuff 1 to 2 cm. was left on the chest wall side. The spleen was completely macerated although not bleeding profusely as the pedicle was not injured. The spleen was removed and the damaged omentum resected. The tail of the pancreas was found lacerated, therefore it was repaired with interrupted cotton sutures. A 3 cm. laceration of the serosa over the greater curvature of the stomach was repaired in a similiar manner. The diaphragm was closed with some difficulty by a two-layer imbricating type of suture, using cotton. The phrenic nerve was paralyzed. The chest was washed out with 2,000 c.c. of saline solution, dusted with 5 Gm. of sulfanilamide, and closed in layers. It was possible to mobilize the muscles sufficiently to secure an adequate closure. A heavy dressing of gauze and wide adhesive was

used to stabilize the chest wall over the large defect. Bronchoscopy was carried out. Although the patient had apparently been in very good condition, just as the bronchoscopy was terminated he became cyanotic and pulseless. An intratracheal tube was immediately inserted and artificial respiration given but with no effect. The heart could not be heard any time after the bronchoscopy.

Post-Mortem Examination.—A post-mortem examination was performed immediately. The heart was found to be somewhat dilated and flabby but that was the only abnormality found with the exception of the conditions described.

Comment.—This patient had a blood pressure of 110/70 and pulse of 110 at the beginning of the operation. The operation was long, two hours and fifty minutes. At the close of the procedure, during which he had been given 500 c.c. of blood, the blood pressure was 90/45 and the pulse rate 112. Preoperative medication consisted of morphine, gr. $\frac{1}{8}$, and scopolamine, gr. $\frac{1}{200}$. In other words there was no atropine effect at all by the time the bronchoscopy was performed. Basing our belief on similar experiences in civilian practice, we are convinced that this represents a "vagovagal reflex." It has been shown that this can be blocked by atropinization and it was our practice before entering the army to give atropine, gr. $\frac{1}{150}$ to $\frac{1}{75}$, intravenously just before doing bronchoscopy. In the light of this case we have resumed this practice in military surgery.

OTHER CONSIDERATIONS

As mentioned at the beginning of this paper it has been necessary, because of existing circumstances, for our team, a thoracic surgical team, to function as a general surgical team. Conversely, it has been necessary for the general surgical teams to handle thoracic cases. This was no doubt often necessary due to the exigencies of war. It is a state, however, to be avoided as far as possible. We firmly believe that thoracic casualties are best treated by thoracic surgeons just as abdominal patients do better when cared for by well-trained abdominal surgeons.

It is obviously impossible to have a well-qualified thoracic surgeon in every medical installation. To achieve the desired end of having chest injuries treated by thoracic surgeons, it is imperative that there be some concentration of cases in certain hospitals. In that way, the thoracic surgeon can devote all his time to the care of thoracic injuries. Even were there not enough thoracic teams to staff this smaller group of hospitals, it is preferable to concentrate the cases so that a few general surgeons will quickly accumulate a large experience rather than to have a large group of relatively inexperienced surgeons caring for them.

The main objection that is usually raised to this plan is that of transporting such very sick patients. It has been our experience that chest patients withstand transportation very well and the injury to operation time is of less importance in this group than in any other. It is true that thoracoabdominal patients should be cared for as soon as possible. We believe, however, that the overall mortality will be decreased if the patients are operated upon by surgeons particularly qualified in thoracic surgery even though the time from injury to operation may have been slightly increased.

SUMMARY

1. The experience of a thoracic surgical team operating in the forward area during a six months' period in the Italian Compaign is presented. During this time the team functioned as a general surgical team but only the patients with thoracic injuries are reported.

2. A total of 192 casualties were treated with a mortality of 3.6 per cent. Of this group the lesion was limited to the chest wall in eighty-two. Penetrating or perforating wounds were present in sixty-three. Nineteen had thoracoabdominal injuries.

3. Of the eighty-two chest wall injuries there was one death, due to *Cl. oedematiens.*

4. A total of twenty-eight thoracotomies were done on the group of sixty-three penetrating or perforating lesions. Fourteen of these were traumatic thoracotomies, that is, patients with large chest wall defects in which the pleural opening was found to be 6 cm. or greater in diameter. Two deaths occurred, a mortality of 7.1 per cent.

5. Seventeen of the observed nineteen patients with thoracoabdominal wounds were operated upon, with an operative mortality of 17.6 per cent.

6. The importance of early, complete expansion of the lung is stressed and methods used to obtain it are discussed.

7. The importance of adequate postoperative care, including rigid attention to removal of all tracheobronchial secretions and the avoidance of anoxia, is emphasized.

8. Certain considerations for more adequate care of the thoracic casualties and the more efficient employment of the available thoracic surgeons are presented.

9. Illustrative case reports are presented.

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EXPERIENCE IN THE LOCALIZATION OF THORACIC FOREIGN BODIES

MAJOR BENJAMIN BURBANK, MAJOR THOMAS H. BURFORD, MAJOR PAUL C. SAMSON, AND LIEUTENANT COLONEL SIDNEY MESIROW, MEDICAL CORPS, ARMY OF THE UNITED STATES

THORACOTOMY for removal of intrapleural and intrapulmonary foreign bodies is a safe and rational procedure only when the preoperative localization of the foreign body has been sufficiently accurate to enable rapid and precise removal. When these procedures become games of "button, button, who has the button?" the complications and mortality rise to prohibitive levels.

While all phases of localization are important, the chief problem that concerns the thoracic surgeon is whether the foreign body lies in the extrapleural tissues or somewhere within the pleural confines. Only by the possession of such accurate preoperative information can a logical operative approach be planned. The foreign body lying within the pleural cavity necessitates a vastly different intellectual and technical approach than the entirely extrapleural chest wall foreign body. Many of these latter can be removed under local anesthesia, and require no specialized training for their proper handling. Once the pleural boundary has been crossed one has to deal with the problems of the open pneumothorax, positive pressure anesthesia, etc.

In a war zone, one may not have at hand the equipment commonly employed for the accurate localization of thoracic foreign bodies such as stereoscopy, laminography, and various reliable localizers. However, we have found in our experience while conducting a chest center in a theater of operations that the lack of these methods did not mean that accurate localization of thoracic foreign bodies could not be attained in almost every case.

To attain this accuracy it became necessary to take careful cognizance of certain principles, and to develop a systematized plan of study. This report is a summary of our experience, as members of an auxiliary surgical group, working in a chest center at a station hospital and a general hospital, in localizing several hundred thoracic foreign bodies. The principles that we have found important and the systematized scheme we have used to localize retained missiles are described.

No originality is claimed. Methods such as the parallax method have not been employed or discussed since we have neither had available, nor needed more complicated armamentaria than that to be described. The importance of systematically following the simple principles outlined herein cannot be overemphasized.

The study of the patient with a foreign body in the thorax begins with the routine posteroanterior and lateral x-ray films. Despite the fact that in many instances these two views suffice for accurate localization, they are in

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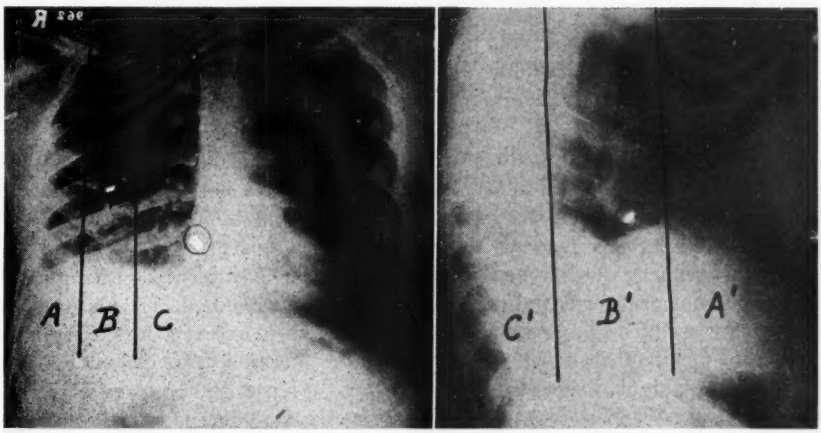
general to be considered little more than scout films to indicate the type of subsequent study. To rely solely on posteroanterior and lateral films is frequently to run into grief, and cannot be too vigorously condemned. That one view alone is worthless for localization seems too obvious to mention, yet not too rarely one is amazed to see a patient who has been fruitlessly explored on the basis of a single film.

In an effort to obtain as much accurate information as possible from posteroanterior and lateral films, we have found it highly valuable to divide the chest into compartments as shown in Fig. 1*A* and *B*. Thus a foreign body can be placed in a certain sector and, immediately, certain facts determined. If a bullet, shell fragment, or other foreign body lies outside these sectors then it is obviously extrapleural. To illustrate the rationale of this method, assume a missile to lie in sector *B-B′* of the right side (See Fig. 1*A* and *B*). From the posteroanterior view alone the foreign body could lie anywhere in the sagittal plane of the right side of the mid-chest. If it were to lie in the anterior chest wall, on lateral view this object should appear in sector *A′*. On the other hand, if it were in the tissues of the posterior chest wall, it should lie in sector *C′*. Since it lies in sector *B′* it is in the mid-coronal plane and hence must be intrapulmonary. If the foreign body lies in sector *B-B′*, it must then lie in the intrapulmonary tissue.



A. *B.*

Fig. 1*A* and *B*.—Division of the lung into arbitrary sectors as described.

The closer a foreign body is to the pleural surface, the more difficult it is to be certain that it lies within lung tissue. If a foreign body lies in sectors other than *B-B′*, reliance cannot be placed upon the posteroanterior and lateral views alone, and recourse must be had to supplemental procedures. Those that we have found invaluable are fluoroscopy with "spot" films, pneumothorax, and pneumoperitoneum. Here we come to a consideration of the information that is to be gained from an examination of the patient and the

proper interpretation of posteroanterior and lateral views of the chest. Following that we will return to a consideration of the systematized scheme that we have found so valuable in attaining accurate localization.

Any patient suspected of harboring a chest wall foreign body should be carefully palpated. This, if successful, is the most accurate of all methods. It is important to remember that one frequently is able to feel chest wall foreign bodies after tenderness and spasm have subsided, when a previous palpation had been fruitless.

Withdrawal of fluid from the chest will, of course, frequently reveal previously undiscovered foreign bodies. The aspiration of blood from the chest, and/or the aspiration or absorption of air with the attendant re-expansion of the lung, and the coincidental positional change of the foreign body, will frequently clinch its localization. In examining serial films one must be alert for these bits of evidence. Foreign bodies that are observed in serial films to have dropped from apex to base are, of course, intrapleural and extrapulmonary. Evidence of characteristic positional change related to movement of the shoulder girdle or large muscle groups of the chest wall is prima facie evidence of an extrapleural position of the foreign body (see Case 14).

If the foreign body has not been localized by adherence to these principles, and lies in one of the sectors mentioned, then the patient is examined under the fluoroscope. If the retained missile is observed to move the distance of an interspace with the varying phases of respiration, it must be assumed to be intrapulmonary. If the foreign body is observed to move synchronously with the pulsations of the heart, then it is either in the lung or in the mediastinum.

The fluoroscopic examination with spot films is done whenever the missile is in a peripheral sector, and where other means have not given its location. Under fluoroscopic vision, the foreign body is rotated to its nearest apparent position to the outer surface of the chest. In this "profile" position one can usually determine whether the retained object is extrapleural, extrapleural and/or intrapleural, or intrapulmonary. A spot film is made in this position for further study. For those patients in whom the issue remains in doubt, a diagnostic pneumothorax will quickly settle the question. Competent opinion must be available, however, to decide whether or not a pneumothorax may be safely given. When a diagnostic pneumothorax is induced and the foreign body undergoes positional changes coincident with that observed in the lung, it must be intrapulmonary. Contrariwise, if it remains in its original position it is obviously extrapulmonary. A combination of the fluoroscopic spot film and pneumothorax technique will also enable one to discover the foreign bodies that lie partly in the extrapleural tissue and partly intrapleurally, a variety that is important for obvious reasons.

Foreign bodies about the diaphragm are notoriously difficult to localize accurately. It is frequently necessary to induce a diagnostic pneumoperitoneum to prove the exact location of retained objects in this region. Once a pneumoperitoneum has been induced, posteroanterior and lateral upright

films should be made. Oblique views and lateral decubitus views will frequently be necessary. If these studies produce even one view showing the foreign body above the diaphragm, then the missile must be intrathoracic and not subdiaphragmatic.

Pneumoperitoneum should, of course, not be done in patients in whom there is evidence of intra-abdominal infection. Those who have recently been subjected to upper abdominal operations will usually not show satisfactory air caps over and around the liver due to adhesions. In left-sided cases, 2 Gm. of soda bicarbonate given orally fifteen minutes before x-ray examination will frequently produce gastric distention sufficient to outline the left diaphragm satisfactorily. Occasionally the employment of both a diagnostic pneumothorax and pneumoperitoneum will be necessary for ultimate localization.

Mediastinal foreign bodies usually offer little difficulty in localization, but require careful evaluation. They most frequently are located in sector *C-B'*. Foreign bodies in this location will frequently be observed to move synchronously with the cardiac pulsations. Some retained missiles in this sector on the left side may be cardiac or pericardial problems and will necessitate careful study and consideration. In those patients in whom the possibility of a perforation of the esophagus exists, it is a matter of direst urgency that this lesion be excluded. All patients must be carefully questioned as to the presence or absence of dysphagia or other symptoms pointing to esophageal injury. These special studies are vitally important in suspected esophageal perforations because of the high mortality that attends overlooked esophageal injuries, and because the surgical approach is different from that employed in the removal of intrapleural, intrapulmonary, or uncomplicated mediastinal foreign bodies. It is very difficult to differentiate some intrapulmonary missiles from those located in the mediastinum. The surgical approach is the same in these two instances.

To illustrate these principles and procedures, the following case records are cited.

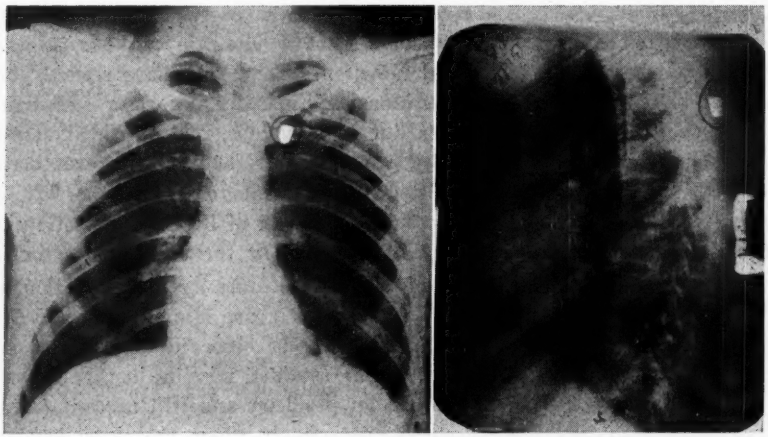
CASE REPORTS

CASE 1 (Fig. 2*A* and *B*).—A patient was struck in the chest by a bullet from an enemy machine pistol. The bullet came to lie in the soft tissues of the posterior thoracic cage, where it could be localized clearly by posteroanterior and lateral x-ray films (Fig. 2*A* and *B*). On admission, the foreign body could not be palpated in the patient, but as spasm and tenderness subsided, the bullet became easily palpable. The missile, found lying in the erector spinae muscles, was removed under local anesthesia.

CASE 2.*—A patient was struck in the right side of the chest by a German rifle bullet. From an examination of the posteroanterior and lateral views, it will be seen that the foreign body lay in sector *B-B'*. From the posteroanterior view alone the foreign body could lie anywhere in the sagittal plane of the right mid-chest. If it were to lie in the anterior chest wall, on lateral view this object would appear in sector *A*. On the other hand, if it were in the tissues of the posterior chest wall, it would lie in sector *C*. Since it lay in the

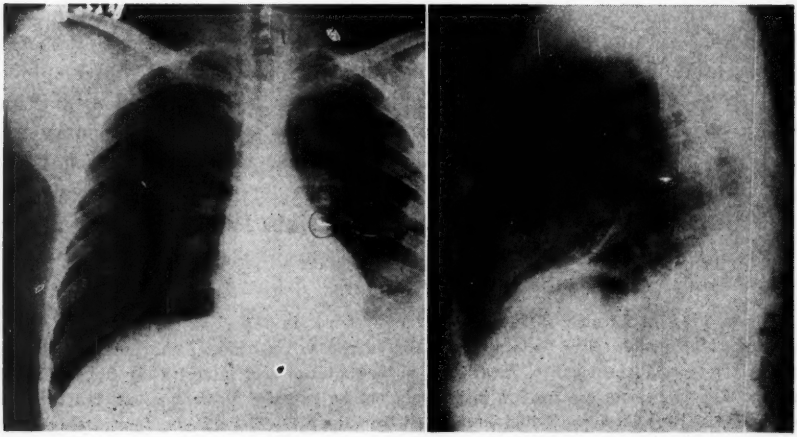
*See Fig. 10*A* and *B*, "The Management of War Wounds of the Chest in a Base Center," Samson et al., p. 22.

mid-coronal plane as shown by the lateral film, there could be no doubt that the foreign body was definitely intrapulmonary. A thoracotomy was done and the missile, the brass jacket of a rifle bullet, was removed from the right middle lobe.



A. *B.*

Fig. 2*A* and *B* (Case 1).—Missile lying in the erector spinae muscles.

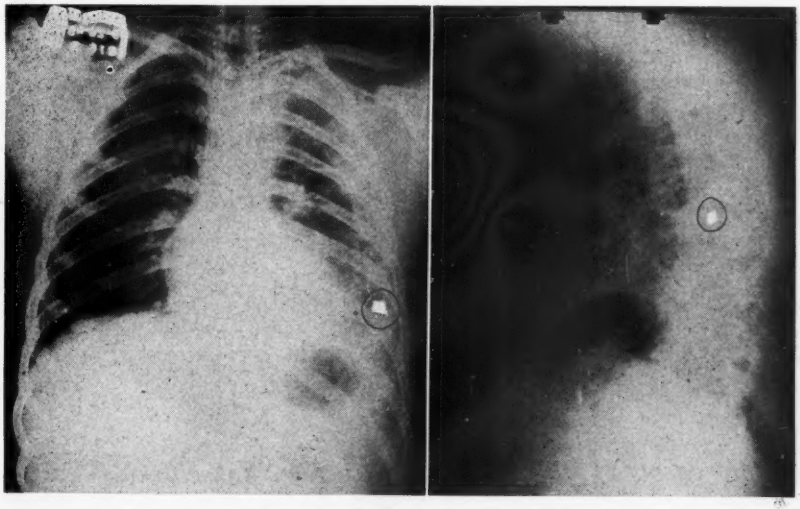


A. *B.*

Fig. 3*A* and *B* (Case 3).—Fragment lying deep within the left lower lobe.

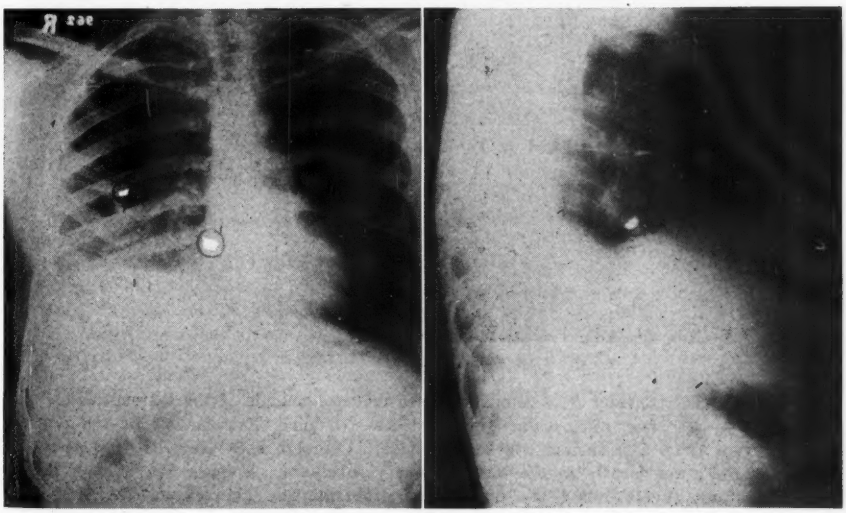
CASE 3 (Fig. 3*A* and *B*).—An Italian prisoner was struck in the chest by a high explosive fragment. Examination of the posteroanterior and lateral views showed the foreign body lying in sector *C-C'*. Fluoroscopic examination revealed it to move synchronously with the respiratory excursions. A thoracotomy revealed the fragment lying deep within the left lower lobe.

CASE 4 (Fig. 4*A* and *B*).—A patient was struck in the left side of the chest by a high explosive fragment. Examination of the posteroanterior and lateral films placed the foreign body in sector *A-C'*. Although operation proved it to be in the left lower lobe, one could not be certain from the films alone that the fragment did not lie outside the lung in the chest wall. The fluoroscopy had projected the missile within the arc of the ribs and thus in lung tissue.



A. *B.*

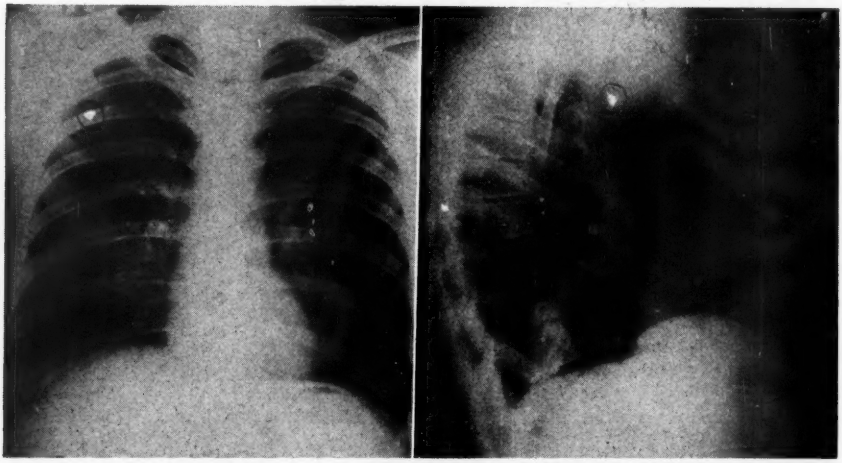
Fig. 4*A* and *B* (Case 4).—Missile in the left lower lobe.



A. *B.*

Fig. 5*A* and *B* (Case 6).—Foreign body No. 1 is in the lung tissue and foreign body No. 2 is in the mediastinum.

CASE 5.*—A patient was wounded in the left side of the chest by a high explosive fragment. Routine posteroanterior and lateral views placed the foreign body in sector *C-B'*. On the posteroanterior view (Fig. 11*A**), it was seen to be just to the right of the midline, and hence was in either the mediastinum or paramediastinal tissue. At operation, the missile was found in the mediastinum lying behind and to the right of the descending aorta. This inability to distinguish will be encountered frequently. In this case, as is generally the case in mediastinal foreign bodies, the differentiation between intramediastinal and paramediastinal localization was not essential since the surgical approach is the same in either case.



A. *B.*

C.

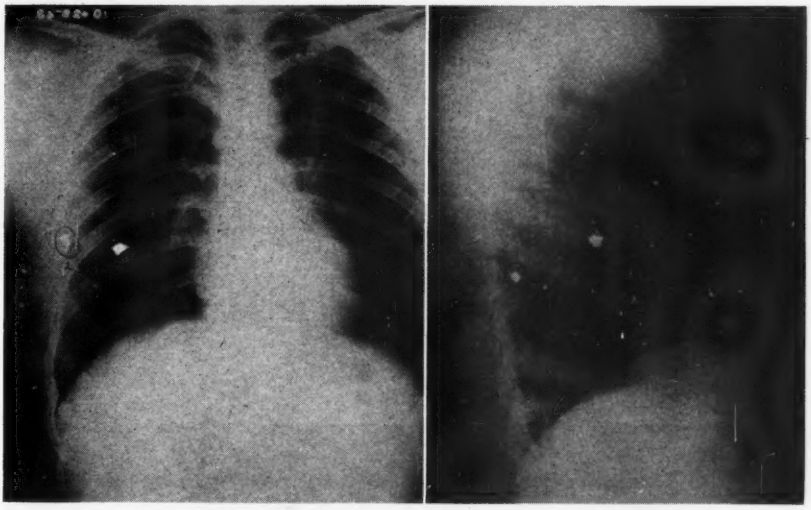
Fig. 6*A*, *B*, and *C* (Case 7).—Revealing the extrapulmonary location of the missile.

CASE 6 (Fig. 5*A* and *B*).—A man received multiple wounds of the extremities and the right side of the chest when a shell exploded close to him. Examination of the posteroanterior view (Fig. 5*A*) showed two foreign bodies. Foreign body No. 1, laying as it did in sector *B-B'*, was clearly in the intrapulmonary substance. Foreign body No. 2 lay in sector *C-B'* and again raised the problem of differentiating between an intrapulmonary and a mediastinal location. Operation proved it to be in the mediastinum, laying just under the mediastinal pleura.

*See Fig. 11*A* and *B*, "The Management of War Wounds of the Chest in a Base Center," Samson et al., p. 23.

CASE 7 (Fig. 6*A*, *B*, and *C*).—A patient was wounded by a high explosive fragment. The foreign body lay in sector *A-B'*. As indicated, it is impossible in this sector to be certain whether the foreign body is intra- or extrapleural. Utilizing fluoroscopy with rotation of the patient, a roentgenogram was taken as shown in Fig. 6*C*. This demonstrates that the foreign body was outside the lung surface. Since it was projected external to the inner margin of the rib it lay in the thoracic wall and not within the pleural cavity. The straight line of increased density was due, in other cases, to an extrapleural hematoma, associated with a metallic foreign body deep in the thoracic wall.

CASE 8 (Fig. 7*A* and *B*).—A patient sustained multiple penetrating high explosive fragment wounds of the chest. There were three foreign bodies visualized and numbered. Foreign body No. 1 and foreign body No. 2 lay in the soft tissues of the lower lateral chest wall. Foreign body No. 3 lay in sector *B-C'*, one of the sectors mentioned previously, which requires supplemental procedures. A diagnostic pneumothorax failed to alter the position of the fragment. Its extrapulmonary location was confirmed by operation, in which a simple incision was made over the ninth interspace.



A. *B.*

Fig. 7*A* and *B* (Case 8).—Foreign bodies No. 1 and 2 are in the soft tissues of the chest wall.

CASE 9 (Fig. 8*A*, *B*, and *C*).—A soldier was wounded by a penetrating high explosive fragment. The examination of Fig. 8*A* and *B* showed the foreign body to lie in sector *B-B'*. However, since the foreign body was quite large, accurate localization might be difficult. In Fig. 8*C*, the patient had developed a hemopneumothorax and there was a definite rotation of the fragment, proving that it must be within lung tissue. This was confirmed by operation.

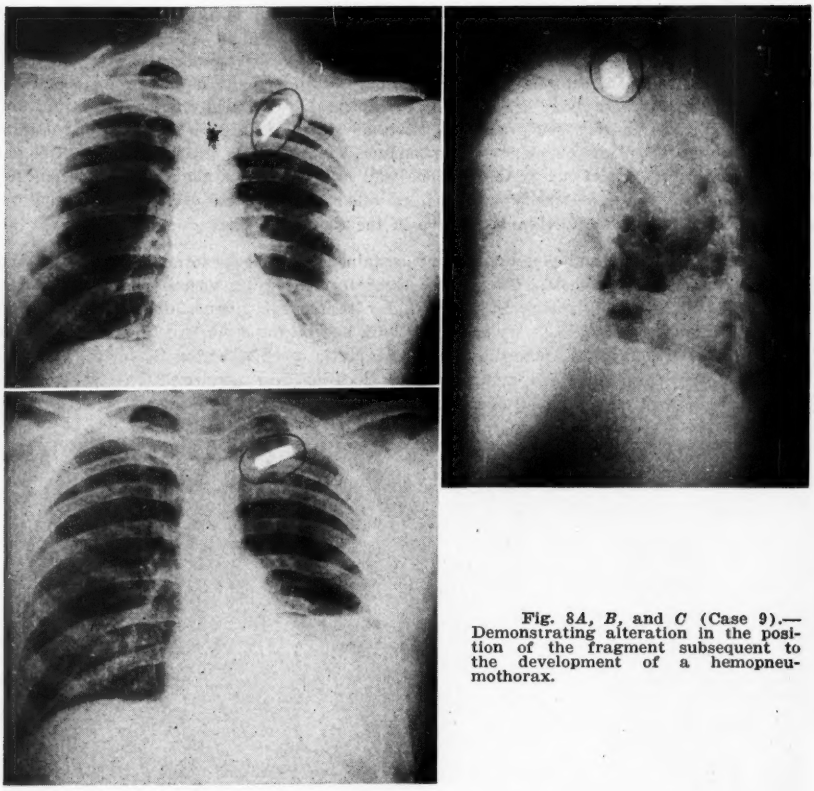
CASE 10.*—One case strikingly demonstrated the changes in position of an intrapulmonary foreign body with re-expansion of the lung following the aspiration of a pneumothorax. Such a phenomenon is incontrovertible evidence of the intrapulmonary location of the foreign body.

CASE 11 (Fig. 9*A* and *B*).—A patient sustained a high explosive fragment wound of the chest. Posteroanterior and lateral views (Fig. 9*A* and *B*) showed the foreign body to lie in sectors *A-B'*, and in the vicinity of the diaphragm. This added markedly to the

*See Fig. 9*A* and *B*, "The Management of War Wounds of the Chest in a Base Center," Samson et al., p. 21.

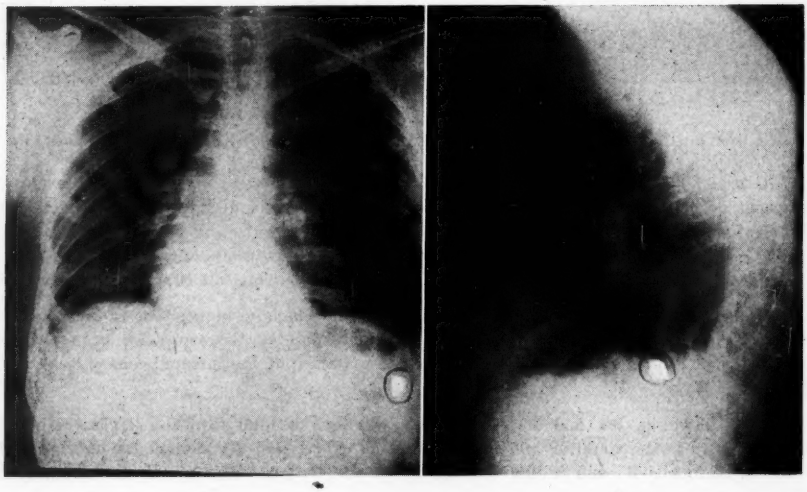
A.

B.



C.

Fig. 8A, B, and C (Case 9).—Demonstrating alteration in the position of the fragment subsequent to the development of a hemopneumothorax.



A.

B.

Fig. 9A and B (Case 11).—Demonstrated value of diagnostic pneumoperitoneum in the accurate localization of foreign bodies in the diaphragmatic region.

difficulty of its accurate localization. Fig. 12*A*, *B*, and *C** was taken after a diagnostic pneumoperitoneum had been induced. Fig. 12*A* and *B** left the issue undecided, while Fig. 12 *C** definitely localized the foreign body in the superior substance of the diaphragm. This oblique view is frequently decisive in placing the exact position of a foreign body in the region of the diaphragm.

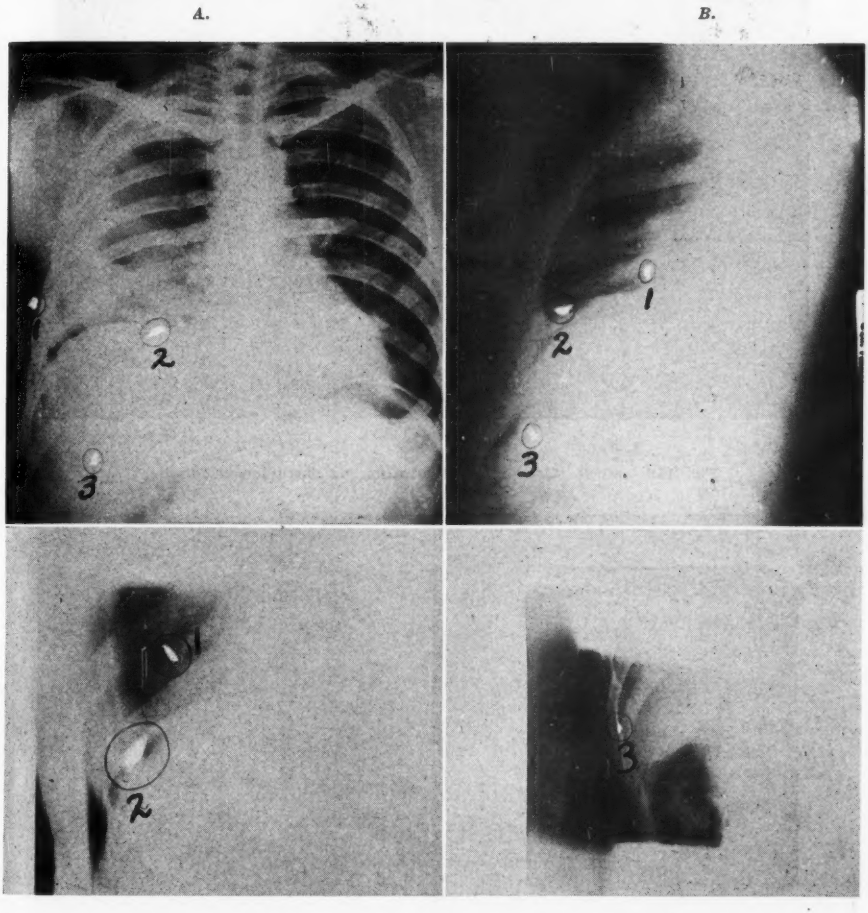


Fig. 10 (Case 12).—*A* and *B*, Diagnostic pneumoperitoneum places foreign body No. 2 above the diaphragm. *C*, "Profile" view of foreign body No. 2 definitely places it within the lung tissues. *D*, Foreign body No. 3 is outside liver.

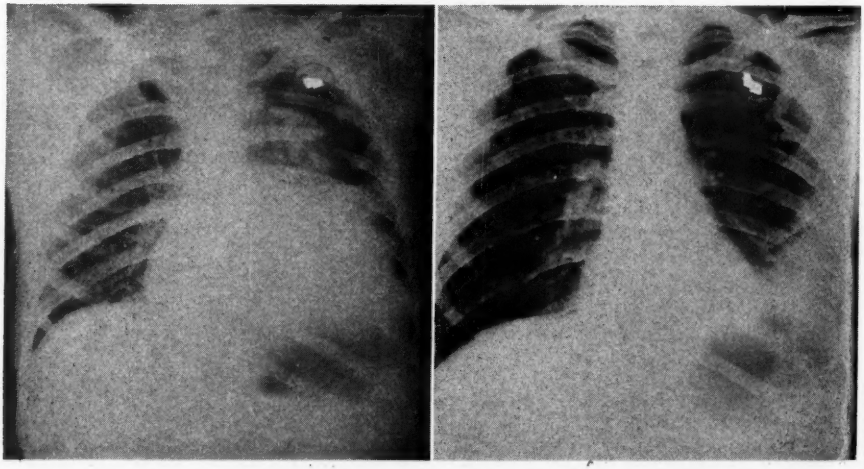
CASE 12 (Fig. 10*A*, *B*, *C*, and *D*).—Here also a pneumoperitoneum has been induced. Foreign body No. 1 was definitely extrapleural, laying in the soft tissues of the chest wall. Foreign body No. 2 lay in the anterior costophrenic region above the diaphragm, evidently intrapulmonary or intrapleural. Fig. 10*C* represents the most clearly defined "profile"

*See Fig. 12*A*, *B*, and *C*, "The Management of War Wounds of the Chest in a Base Center," Samson et al., p. 24.

view of foreign body No. 2, and because it projects the missile in lung tissue, proved it not to be in the intercostal soft tissues. At thoracotomy, the shell fragment (No. 2) was found in the substance of the middle lobe. Fig. 10*D* definitely revealed that foreign body No. 3 lay outside of the liver.

A. *B.*

Fig. 11*A* and *B* (Case 13).—Illustrating an intrapleural missile.



A. *B.*

Fig. 12*A* and *B* (Case 14).—Missile does not move with re-expansion of the lung, and a change of axis in its position can be explained by the difference in the position of the shoulder girdle in these two views.

CASE 13 (Fig. 11*A* and *B*).—In one case the foreign body lay in sector *B-C'*, and this emphasized the difficulties of differentiating between an intrapleural and intrapulmonary location by relying solely on the formal posteroanterior and lateral views. At operation,

the foreign body was found lying free in the intrapleural space. As described before, the concomitant clotted hemothorax necessitated operation and prevented the use of a diagnostic pneumothorax.

CASE 14 (Fig. 12*A* and *B*).—In Fig. 12*A*, the foreign body was present in sector *B* of the chest. The foreign body seemed suspended high up in the center of the pneumothorax pocket without any visible means of support. Since it did not drop to the bottom, it could not possibly lie free in the pleural cavity. Fig. 12*B* showed complete re-expansion of the lung. There was no significant positional change of the foreign body coincident with pulmonary re-expansion. The slight change in axis of the metallic fragment was due to the elevation of the shoulders. This phenomenon can frequently be helpful in localizing foreign bodies in and about the scapula and clavicle. At operation this shell fragment was removed from deep to the pectoralis major muscle, just inferior to the left clavicle.

SUMMARY AND CONCLUSIONS

The importance of accurate localization of thoracic foreign bodies has been stressed. The peculiar problems associated with foreign bodies of the thorax have been emphasized.

An effective plan of study for the localization of thoracic foreign bodies has been presented. Cases have been presented and principles discussed.

Utilization of this scheme of study enables accurate and rapid localization of thoracic foreign bodies encountered in a war zone.

Meeting of the American Association for Thoracic Surgery

The American Association for Thoracic Surgery will hold its next meeting in Detroit, May 29, 30, and 31, 1946, with headquarters at the Statler Hotel. Dr. Edward J. O'Brien is the chairman of the local committee on arrangements, but requests for reservations should be sent to the hotel.

Applications for places on the program must be submitted before March 1, 1946, to the secretary, Dr. Richard H. Meade, Jr. It is requested that abstracts of the proposed papers be submitted in triplicate. The members of the program committee are: Dr. Claude S. Beck, chairman, Dr. I. A. Bigger, Dr. Evarts A. Graham, Dr. Richard H. Meade, Jr., and Dr. Edward J. O'Brien.

Nominations for membership must be sent before Feb. 1, 1946, to Dr. Ethan F. Butler, 956 W. Water St., Elmira, New York, chairman of the membership committee.

The Rose Lampert Graff Prize for the best paper submitted for the meeting will be offered again this year. The committee to make this award is composed of Dr. Frank B. Berry, chairman, Dr. Richmond L. Moore, Dr. Max Pinner, and Dr. J. J. Singer. Anyone desiring to enter this competition must submit abstracts and the completed papers. The papers will be considered first by the program committee, and then forwarded to the prize committee.